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TABLES OF COMPUTED THERMODYNAMIC PROPERTIES
OF
MILITARY GUN PROPELLANTS

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Department of the
Ordnance Management
BALLISTIC RESISTANCE LABORATORIES

ABERDEEN PROVING GROUND, MARYLAND

BALLISTIC RESEARCH LABORATORIES

MEMORANDUM REPORT NO. 1338

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Aberdeen Proving Ground, Md.
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ABSTRACT

Thermodynamic properties of all commonly used military gun propellants plus some experimental propellants are presented in tabular and graphical form. For the military propellants, these properties are given over a loading density ranging from 0.05 to 0.4 gm/cc. Comparisons are made between the propellants on the basis of "force" and isochoric flame temperature. The tables and data presented herein can be used for gun design computations.

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I INTRODUCTION

Within the past two years a general program for the computation of ballistic trajectories inside of a gun⁽¹⁾ has been set up at these laboratories on the high speed digital computer, CRNVAC. A portion of the input data required for this program is thermodynamic properties of the combustion products such as; flame temperature, force, covolume, and specific heat ratio.

Tables which have been used in the past as a source of this information have been compiled either from obsolete thermodynamic data, or computed using various simplifying assumptions. In addition, these tables have given the thermodynamic properties for a single density of loading for the gun (usually 0.2 gm/cc) whereas most guns operate over a wide range of loading densities. Since the thermodynamic properties of the propellant gases vary with loading density, it would be useful to compute the properties of all the common military propellants over the range of loading densities normally encountered in gun firings.

In the following report, the thermodynamic properties for all the common military propellants and some experimental propellants are given. For the military propellants (with the exception of M7 and M20) these properties are given over a loading density range from 0.05 to 0.4 gm/cc. In addition the thermodynamic properties of three other types of propellants are examined:

- (1) Nitrocellulose at varying percentages of nitration.
- (2) M1 propellant contaminated with varying percentages of water and/or ethyl alcohol.
- (3) Double base propellant with varying proportions of nitrocellulose and nitroglycerine.

To carry out the extensive computations required for the preparation of this report, a digital computer program designed to

compute the thermodynamic properties of gun propellants was used on the ORDVAC. This program was initially formulated by Brinkley⁽²⁾ and revised by Leser⁽³⁾ and has been used by the authors for about 1/2 year. The computer program as devised by Leser has been revised by one of the authors (Baer) so that the flame temperature of the propellant can be computed together with the thermodynamic properties at the flame temperature. This revised computer program is the one now in current use.

II COMPUTATIONAL RESULTS

The data in this report have been organized in the following manner:

- (1) Tables listing propellant composition and important thermodynamic properties.
- (2) Tables of input thermodynamic data used in the program.
- (3) Figures presenting in graphical form some of the particular thermodynamic properties of military propellants.
- (4) An appendix presenting the detailed computed data for all propellants considered.

For ease in locating a particular piece of detailed information in the appendix, a table of contents appears at the beginning of that section.

In Table I, composition and thermodynamic data at the flame temperature are given for 16 military propellants. In Table II, data are given for 7 experimental propellants. In Table III data are given for M1 propellant contaminated with water and/or ethyl alcohol and for nitrocellulose propellants with varying degrees of nitration. In Table IV data are given for experimental double base propellants.

Tables I through IV have been arranged in a format similar to that of the Picatinny tables⁽⁴⁾ with the following differences;

(1) For each propellant in Tables I, II, and III percentage compositions are given; the composition under the column marked "S" (for specification) is the composition as given in the Picatinny tables. The composition under the column marked "B" (for Brinkley) is a normalized composition used in computing the thermodynamic properties of the propellant. The difference between the two compositions is due to two factors: (1) percentages listed in the Picatinny tables added up to values greater than 100%, and so had to be normalized to a percentage composition; (2) in some propellants inorganic salts, such as potassium sulfate, potassium perchlorate, etc. had been added. Since the Brinkley code does not have provision for the inclusion of these salts, they were normalized out of the composition.

It is believed that, with the exception of M7, the omission of these salts will not appreciably change the thermodynamic results.

(2) Data in Tables I, II, and III are reported at a density of loading of 0.2 gm/cc. Data in Table IV are reported for densities of loading of both 0.1 and 0.15. The difference in the densities of loading between Table IV and the other three tables is that the data in Table IV were computed in the support of an experimental program for the measurement of propellant gas temperatures in a closed bomb.

(3) The propellant Force "P" in all four tables was computed at the loading density shown. This was done to give a direct comparison between the force values for the military propellants and the experimental propellants.

It is of interest to compare the force and flame temperatures for these propellants. In Table V, military and experimental propellants are listed in order of decreasing force; in Table VI in order of decreasing adiabatic flame temperature. It will be noted that for some propellants there is a difference between the force

rating and the flame temperature rating. The special propellants of Tables III and IV were not included in this rating in order to avoid confusion.

The thermodynamic data in Table I are given for a standard loading density of 0.2 gm/cc. To examine the variation with loading density of the thermodynamic properties at the flame temperature, the thermodynamic properties for all the military propellants (with the exception of M7 and M26) were computed for five loading densities: 0.05, 0.1, 0.2, 0.3, 0.4. This range was chosen to account for most of the gun pressure range (1000 - 100,000 psi). Table VII gives these thermodynamic properties for the above loading densities.

One of the results which can be derived from the Brinkley thermodynamic computations is the covolume correction. This correction appears in the Nobel - Abel equation of state for propellant gas as follows:

$$P(V - \eta) = nRT_0 = F \quad (1)$$

Since the volume term in equation (1) is the reciprocal of the loading density, equation (1) can be written as follows:

$$P\left(\frac{1}{\rho} - \eta\right) = F \quad (2)$$

Expanding and rearranging (2) we obtain:

$$\frac{P}{\rho} = F + \eta P \quad (3)$$

Equation (3) can be represented as a linear plot of P/ρ vs P in which the slope is the covolume η , and the intercept with $P = 0$, the propellant force, F . When P/ρ vs P is plotted from the Brinkley computations, the resulting plot is not linear, the data points falling on a smooth curve. For this reason, the covolume correction will vary with the constant volume chamber pressure P . To determine this variation a cubic equation in pressure, P , was fitted by least squares to the data of P/ρ vs P , giving the following relation:

$$P/p = F_1 + a_1 P + a_2 P^2 + a_3 P^3 \quad (4)$$

The covolume is the first derivative of equation (3) thus:

$$\gamma = a_1 + 2a_2 P + 3a_3 P^2 \quad (5)$$

In equation (5) a_1 is the linear covolume term. In Table VIII the value of the coefficients F_1 , a_1 , $2a_2$, and $3a_3$ are listed for the military propellants. In Table VII, for each military propellant, the covolume correction is given for each density of loading.

In Table VII is also given the intercept propellant force F_1 and a force computed from the relation:

$$F = nRT_v \quad (6)$$

The force F is tabulated for each propellant and for each density of loading.

The intercept force F_1 can be used to compute the pressure developed by burning the propellant in an adiabatic closed bomb at a loading density p . The pressure developed can be computed by solving the cubic equation:

$$p a_3 P^3 + p a_2 P^2 + (p a_1 - 1)P + p F_1 = 0 \quad (7)$$

Since the value for the coefficient a_3 is quite small, little error will be made at low loading densities if one drops the cubic term, in which case solution to the resulting quadratic equation can be obtained by normal algebraic methods. Complex algebraic solutions exist for the cubic equation, one method being listed in the Chemical Rubber Handbook. (5)

A number of military guns, especially those of the howitzer class, can be approximated by a simple gun model. In this model, it is assumed that the projectile does not move to any appreciable extent while the propellant is burning. After the propellant is burned, the projectile is accelerated by the expanding hot gases. It is of interest in interior ballistics to show the relation between gas pressure and temperature while the combustion gases are undergoing an isentropic expansion behind the projectile. A

pressure-entropy diagram is one way in which this process can be illustrated; therefore, pressure-entropy diagrams have been plotted from the results of the Brinkley computation on the military propellants. These plots are shown in Fig. 1 - 14.

These figures are a graphical representation of the relationship between gas density, temperature, pressure, and entropy for the combustion gases of each of the military propellants. The dotted line labeled T_A represents the flame temperature of the propellants.

These figures can be used to predict the gas temperature in a gun, provided that the pressures are known. For example, suppose M1 propellant at a density of loading of 0.3 gm/cc is burned in a gun chamber and burnout of the propellant occurs before the projectile moves to any appreciable extent. On Fig. 1, the pressure-entropy diagram for M1 propellant, the intersection of the density of loading line $\rho = .3$ with the isochoric flame temperature line T_A is the condition in the chamber at burnout of the propellant. Under these conditions $T_A = 2440^\circ\text{K}$, the pressure $P = 60,700$ psi (this could be checked against the experimental pressure), and the entropy $S = 2.122$ cal/gm $^\circ\text{K}$. If one assumes that motion of the projectile causes isentropic expansion of the gas; then one can determine the temperature of the gas at any point along the gun tube provided the pressure at that point is known. For example, assume that muzzle pressure of the gun has been found to be 5,000 psi. Then dropping down the entropy line at 2.122 until the 5,000 psi pressure line is reached, one finds that the gas temperature is 1540°K .

In closed chamber firings, the relationship between pressure and temperature is generally unknown because of heat loss from the chamber. From these figures the temperature of the propellant gas can be predicted, knowing the loading density and the experimental pressure; since the gas temperature will be the intersection of the pressure line with the gas density line.

Other types of diagrams can be plotted from the thermodynamic data obtained from the Brinkley computations, but in lieu of plotting more diagrams the thermodynamic data is presented in the appendix for each propellant. In addition to the thermodynamic data, there are presented the equilibrium combustion gas composition at a particular gas density and temperature. The range of gas temperatures presented in these tables depends upon the range of gas temperatures presented in the pressure-entropy figures. For high gas densities the temperature range is narrow and for low gas densities, the temperature range is wide. Further details on these tables is presented in the appendix.

III MISCELLANEOUS COMPUTATIONS

It is of interest to the manufacturer and user of military propellants to determine the effect of water and/or ethyl alcohol on the thermodynamic properties (particularly the flame temperature and force) of the propellant. The propellant chosen for this investigation was M1 at a loading density of 0.2 g/cc. The first portion of Table III gives the propellant composition and a summary of the propellants thermodynamic properties. The format for this table is the same as that used in Tables I and II. The propellant composition column headed by the letter "S" is the standard composition showing the amount of alcohol and/or water added. The composition column headed by the letter "B" is the normalized propellant composition used in the Brinkley computations. In this table amounts of water or ethyl alcohol added to the propellant were varied from 0 - 6%. In one propellant a 3% - 3% mix of ethyl alcohol - water was added to determine the effect of a mixture. A plot of the flame temperature vs percentage water or ethyl alcohol added is shown in Fig. 16. This figure can be used to estimate the effect on flame temperature of alcohol - water mixtures, which can be made by assuming that the drop in flame temperature due to water

can be added to the drop due to alcohol. On the graph this estimate can be made by measuring the temperature drop due to the addition of water with dividers and then spacing off this distance below the flame temperature due to the alcohol addition. For low (less than 1%) percentages of alcohol and water, this method will give values within 3% of the computed value. For higher percentages, the error is greater, for instance a 3% - 3% mixture gives an estimated value of 2171°K, the computed value being 2192°K. Detailed tables for these propellants are presented in the appendix.

In the latter portion of Table III are shown the composition and thermodynamic properties of pure nitrocellulose propellants where nitrogen content varies from 12.6% to 13.2%. The detailed computational results are given in the appendix.

Recently, at this laboratory, flame temperature studies were made on a series of double-base propellants in which the nitro-glycerine concentration was varied from 0% to 20%. In Table IV, the computed composition and thermodynamic properties for these experimental double base propellants are given for two loading densities, 0.10 and 0.15 gm/cc. As would be expected, the flame temperature and the propellant force increase as the nitro-glycerine content increases. Detailed computations on these propellants are given in the appendix.

In all of the computations, the combustion products have been assumed to behave as real gases. It is of interest to see what would happen to the thermodynamic properties of the propellant, if this assumption were not made; e.g., assume the combustion products behave as ideal gases. In the Brinkley code this is done by setting the virial coefficients equal to zero. In the appendix are listed the thermodynamic properties for M1 propellant at a density of loading of 0.2 gm/cc. Comparison of thermodynamic properties at the flame temperature gives the following results:

M1 Propellant

$$\rho = 0.2 \text{ gm/cc}$$

	Real Gas	Ideal Gas
Flame Temp. °K	2433	2427
γ	1.264	1.263
Mol. wt.	22.13	22.10
P psi	35,019	26,494

From the above, the only significant difference in results is in the constant volume combustion pressure, the ideal gas combustion pressure being 24.35% lower than the real gas combustion pressure.

THERMODYNAMIC DATA

Thermodynamic data used in these computations are presented in Tables IX through Table XII. Table IX shows the atomic composition and heat of formation of military and experimental propellants. These data, together with the loading density, are all that are needed for propellant input to the Brinkley program. In Table X the atomic composition and heats of formations are given for the special propellants, that is, the M1 propellant containing various concentrations of water and ethyl alcohol, and the experimental double base propellants. Table XI shows the atomic composition and heats of formation for the propellant reactants. Included in this table is the source of the thermodynamic data used to compute the heats of formation of the reactants.

It was assumed in computing the heats of formation of the propellants considered in this report that the total heat of formation was the sum of the proportional heats of formations of the individual reactants. Thus heats of polymerization, or any heat released by chemical reaction between the propellant reactants prior to burning, were not considered.

The heats of formation of the propellant combustion products are given in Table XII, and in Table XIII, a correction factor to correct

the value of the internal energy of the combustion products from a level of 0°K (the level being used in the Brinkley calculations) to a level of 298°K, the temperature level of the heats of formation of the propellant reactants. Tables of internal energies, chemical potential, specific heats, and virial correction for each of the combustion products are presented in Leser's report⁽³⁾ and will not be repeated here.

V DISCUSSION

This report presents thermodynamic data regarding the combustion properties of military gun propellants, plus some data concerning experimental propellants. These data must be regarded as tentative, pending revisions in the thermodynamic data used in the computations. In future revisions, both the ideal gas thermodynamic properties, and the real gas virial corrections of the combustion products will be replaced. In addition, the thermodynamic code will be set up in such a way as to account for the presence of the inorganic salts used in the propellants.

In Leser's report⁽³⁾ one serious error occurred which, until located and corrected, markedly influenced the shape of the pressure-entropy diagram. This error was in the sign of the correction to the activity coefficient for gas imperfection. The correct equation is [eq. (11) in Leser's report]:

$$+ \log \gamma_1 = \frac{(B + nB_1) \rho}{r_0} + \frac{(nC + n^2 C_1/2) \rho^2}{M_0^2}$$

The ideal gas thermodynamic data and the real gas virial data for ammonia had discontinuities and irregularities when plotted as a function of temperature. In Fig. 15, the effects of these irregularities upon the combustion gas composition for M-1 at 0.2 gm/cc loading is shown. Since the proportion of ammonia in

the combustion products is very minor, any changes in the ammonia data would not be expected to change the overall thermodynamic properties of the propellant to any great extent. A severe error in the chemical potential for ammonia at 1700°K was corrected in the process of these computations and is not present in the results.

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5. "Handbook of Chemistry and Physics" pg. 295, 38th Edition (1956 - 1957) Chemical Rubber Publishing Co., Cleveland, Ohio, 1956.
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TABLE
Formulae and Calculated Thermochemical

[illegible]

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TABLE I
Calculated Thermochemical Values for Military Propellants

M7 JAN P-659		M8 JAN F-781		M9 MIL P-20306		M10 FA PD-123		M12 JAN P-528		M14 JAN P-309		M15 MIL P-682A		M17 MIL PD-682A		M18 FA PD-26A		M26 PA PD-329		IMR JAN P-733	
B	S	B	S	B	S	B	S	B	S	B	S	B	S	B	S	B	S	B	S	B	S
3.71	54.00	52.60	52.15	58.33	57.75	96.93	93.00	89.63	97.70	88.02	90.00	20.00	20.00	21.98	22.00	79.60	80.00	67.22	67.25	89.92	100.00
13.15	13.15	13.25	13.25	13.25	13.25	13.15	13.15	13.15	13.15	13.15	13.15	13.15	13.15	13.15	13.15	13.15	13.15	13.15	13.15	13.15	13.15
3.17	43.00	43.47	43.00	40.40	40.40							19.00	19.00	21.48	21.50	9.95	10.00	24.99	25.00		
																			0.75		
			1.25		1.50														0.70		
												54.70	54.70	54.65	54.70						
								7.34	8.00	7.82	8.00									7.19	8.00
										1.96	2.00					8.96	9.00				
						0.99	1.00	0.73	0.80	0.98	1.00					1.00	1.00			0.63	0.70
0.97	0.70	0.61	0.64	0.76	0.75							6.00	6.00	1.50	1.50			6.00	6.00		
						0.10	0.10							0.10	0.10			0.30	0.30		
												0.30	0.30								
0.86	0.80	0.40	0.40	0.51	0.50	1.48	1.50	1.38	1.50	0.98	1.00	0.30	0.30	0.30	0.30	0.50	0.50	1.20	1.20	1.15	1.50
						0.49	0.50	0.92	1.00	0.25	0.25			0.10	0.10			0.30	0.30	0.90	1.00
1.29	1.20																				
		3.03	3.00																		
						1.00															1.00
	7.80							0.75													
								0.75													
3666		3757		3840		3934		3838		3724		2543		2974		2592		3032		2677	
391,146		396,735		396,340		346,180		336,390		326,140		326,855		359,483		330,625		361,638		337,687	
0.0447		0.0441		0.03700		0.04105		0.04333		0.04330		0.04637		0.04447		0.04444		0.04333		0.04222	
1.214		1.211		1.207		1.235		1.244		1.252		1.260		1.241		1.256		1.238		1.243	
3050		3102		3181		2457		2297		2176		2020		2396		2063		2498		2315	
-		30.23		30.64		29.69		29.92		30.24		30.15		29.92		30.53		-		29.69	
-		-		-		1.67		-		1.61		1.66		1.67		-		1.62		-	
0.2		0.2		0.2		0.2		0.2		0.2		0.2		0.2		0.2		0.2		0.2	

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TABLE II

Formulae and Calculated Thermochemical Values for Experiment

Propellant Specification	T 20		T 25 PA PD-329		T 29		T 31				
	B	S	B	S	B	S	B		S		
Nitrocellulose	19.94	20.00	73.21	73.25	45.95	46.00	29.79	24.83	30.00	25.00	30.00
$\frac{1}{2}$ Nitrogen	13.15	13.15	13.15	13.15	13.15	13.15	12.20	13.35	12.20	13.35	12.20
Nitroglycerine	12.96	13.00	19.99	20.00	21.48	21.50	42.70		43.00		
Barium Nitrate				0.75							
Potassium Nitrate				0.70							
Lead Carbonate		1.00									
Nitroguanidine	59.82	60.00			30.67	30.70					
Dinitrotoluene											
Dibutylphthalate	4.00	5.00									
Diphenylamine											
2-Nitrodiphenylamine											
Ethyl Centralite	2.00	2.00	5.00	5.00	1.50	1.50	1.99		2.00		
Graphite			0.30	0.30	0.10	0.10					
Cryolite						0.30					
Ethyl Alcohol	0.30	0.30	1.20	1.20	0.30	0.30	0.50		0.50		
Water			0.30	0.30							
Carbon Black							0.20		0.20		
Diethylphthalate											
Potassium Sulfate											
Fin											
Isochoric Flame Temp., °K, T_v	2325		3090		3215		3688				
Force, ft - lb/lb, F	307,484		358,113		370,235		392,299				
Gas Volume, moles/lbm, η	.04733		.04171		.04147		.03867				
Ratio of Specific Heats, γ	1.268		1.237		1.232		1.213				
Isobaric Flame Temp., °K, T_p	1834		2498		2610		3040				
Specific Gravity	1.66		1.62		1.66		1.62				
Loading Density, gm/cc	0.2		0.2		0.2		0.2				

TABLE II

Calculated Thermochemical Values for Experimental Propellants

T 29		T 31				T 32				T 33				T 34	
B	S	B		S		B		S		B		S		B	S
5.95	46.00	29.79	24.83	30.00	25.00	30.80	25.67	30.95	25.80	21.19	35.27	21.30	35.45	20.00	20.00
5.15	13.15	12.20	13.35	12.20	13.35	12.20	13.35	12.20	13.35	12.20	13.35	12.20	13.35	12.20	12.60
1.48	21.50	42.70		45.00		34.83		35.00		34.83		35.00		19.00	19.00
0.67	30.70													54.70	54.70
														4.00	4.00
														2.00	2.00
1.50	1.50	1.99		2.00		7.91		7.95		7.91		7.95			
0.10	0.10														
	0.30														0.30
0.30	0.30	0.50		0.50		0.50		0.50		0.50		0.50		0.30	0.30
		0.20		0.20		0.30		0.30		0.30		0.30			
3215		3688				3087				3135				2571	
370,255		390,297				304,529				368,149				329,028	
.04147		.03067				.04249				.04226				.04595	
1.232		1.213				1.240				1.238				1.257	
2.10		3040				2490				2532				2045	
1.02		1.02				1.02				1.02				1.65	
0.2		0.2				0.2				0.2				0.2	

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TAI
Formulae and Calculated Thermod

Propellant	M 1 0-0		M 1 2-0		M 1 4-0		M 1 6-0		M 1 8-0	
	B	S	B	S	B	S	B	S	B	S
Nitrocellulose	84.18	85.00	82.52	85.00	80.95	85.00	79.43	85.00	82.52	85.00
% Nitrogen	13.15	13.15	13.15	13.15	13.15	13.15	13.15	13.15	13.15	13.15
2-nitrotoluene	9.20	10.00	9.71	10.00	9.52	10.00	9.35	10.00	9.71	10.00
diethylphthalate	4.95	5.00	4.85	5.00	4.76	5.00	4.67	5.00	4.85	5.00
Diphenylamine	0.99	1.00	0.97	1.00	0.95	1.00	0.93	1.00	0.97	1.00
Ethyl Alcohol			1.94	2.00	3.81	4.00	5.61	6.00		
Water									1.94	2.00
Isochoric Flame Temp., °K, T_v	2510		2362		2234		2127		2029	
Force, ft - lb/lb., P	312,220		301,113		290,393		280,379		303,304	
Gas Volume, moles/gm, η	.04664		.04562		.04627		.04646		.04680	
Ratio of Specific Heats, γ	1.263		1.263		1.272		1.274		1.262	
Adiabatic Flame Temp., K, T_p	1987		1863		1756		1670		1925	
Loading Density, gm/cc	0.2		0.2		0.2		0.2		0.2	

TABLE III

Calculated Thermodynamic Values for Special Propellants

	M 1 0-3		M 1 0-4		M 1 0-6		M 1 3-3		NC 12.6	NC 12.8	NC 13.0	NC 13.1	NC 13.15	NC 13.2
	B	S	B	S	B	S	B	S						
00	82.52	85.00	80.95	85.00	79.43	85.00	79.43	85.00	100.00	100.00	100.00	100.00	100.00	100.00
15	13.15	13.15	13.15	13.15	13.15	13.15	13.15	13.15	12.6	12.8	13.0	13.1	13.15	13.2
00	9.71	10.00	9.52	10.00	9.35	10.00	9.35	10.00						
00	4.85	5.00	4.76	5.00	4.67	5.00	4.67	5.00						
00	0.97	1.00	0.95	1.00	0.93	1.00	0.93	1.00						
00														
00							2.80	3.00						
	1.94	2.00	3.61	4.00	5.61	6.00	2.80	3.00						
	2429		2352		2280		2192		3060	3145	3230	3272	3292	3317
	303,304		291,974		287,024		283,406		344,001	349,924	355,681	358,413	359,632	361,411
	.04480		.04497		.04511		.04609		.04046	.04006	.03967	.03947	.03957	.03928
	1.232		1.264		1.263		1.269		1.232	1.230	1.227	1.226	1.225	1.224
	1925		1861		1805		1727		2424	2557	2632	2669	2657	2710
	0.2		0.2		0.2		0.2		0.2	0.2	0.2	0.2	0.2	0.2

TABLE IV
Formulas and Calculated Thermodynamic Values for Experimental Double - Base Propellants

Propellant	0% NC 100% NC	5% NC 95% NC	10% NC 90% NC	15% NC 85% NC	20% NC 80% NC
Nitrocellulose	100.00	95.00	90.00	85.00	80.00
5 Nitroglycerine	13.15	13.15	13.15	13.15	13.15
Nitroglycerine	0	5.00	10.00	15.00	20.00
Isobaric Flame Temp., °K, T _i	3247	3255	3267	3274	3282
Pressure, P _i = lb/in ² , P	330,000	355,000	366,874	371,923	377,949
Gas Volume, v _g /gm, v	0.9943	0.9938	0.9900	0.9872	0.9835
Ratio of Specific Heats, γ	1.226	1.226	1.220	1.220	1.214
Isobaric Flame Temp., °K, T _f	2648	2636	2602	2573	2558
Loading Density, gm/cc	0.10	0.15	0.10	0.15	0.15

TABLE V

Military and Experimental Propellants in
order of Decreasing Force

Propellant		Force @ $\rho = 0.2$ ft.- lb. ft.
1.	M9	396,840
2.	M8	396,735
3.	T31	391,299
4.	M7	391,146
5.	M2	372,639
6.	T29	370,235
7.	T33	368,149
8.	M5	367,146
9.	T32	364,529
10.	M26	361,638
11.	M17	359,483
12.	T25	358,113
13.	M10	346,180
14.	IMR	337,687
15.	M12	336,390
16.	T34	329,028
17.	M15	328,855
18.	M14	328,140
19.	M18	320,655
20.	M6	317,830
21.	T20	307,488
22.	M1	305,846
23.	MTAI	288,475

TABLE VI

Military and Experimental Propellants in
order of Decreasing Adiabatic Flame Temperature

Propellant		Adiabatic Flame Temperature, $T_v @ p = 0.2$ $^{\circ}K$
1.	M9	3840
2.	M3	3757
3.	T31	3688
4.	M7	3686
5.	M2	3372
6.	M5	3294
7.	T29	3215
8.	T33	3135
9.	M26	3092
10.	T25	3090
11.	T32	3087
12.	M10	3034
13.	M17	2974
14.	IMR	2877
15.	M12	2858
16.	M14	2724
17.	M18	2591
18.	M6	2583
19.	T34	2571
20.	M15	2545
21.	M1	2433
22.	T20	2325
23.	M1A1	2258

TABLE VII

Variation of the Thermodynamic Properties of Military Propellants with Loading Density

Propellant	Loading Density lb/oz	T °K	E cal/g	P psi	S cal/°K	Z	S cal/°K	H cal/g	M lb/mole	\ln^3 lb	P_1 ft-lb/lb	P ft-lb/lb
M1	.05	2435	625.7	7,073	34.34	1.265	2.319	1174	22.065	36.656	304,895	303,616
	.1	2407	624.7	15,166	34.50	1.266	2.250	1173	22.090	34.242		305,835
	.2	2353	622.1	35,019	34.86	1.264	2.174	1170	22.192	31.084		305,846
	.3	2243	624.9	60,660	35.31	1.265	2.123	1167	22.414	27.670		305,496
M1A	.05	2237	625.4	95,056	35.85	1.266	2.081	1163	22.803	24.438		304,884
	.1	2142	578.1	6,564	34.31	1.271	2.319	1182	21.631	36.253		287,708
	.2	2031	577.0	14,205	34.50	1.271	2.247	1181	21.682	34.861		288,005
	.3	2031	574.5	33,118	34.94	1.270	2.170	1148	21.920	31.707		288,475
M2	.05	2317	572.6	57,660	35.50	1.269	2.117	1146	22.368	28.201		288,876
	.1	2237	562.4	66,728	36.16	1.268	2.075	1142	22.399	24.733		289,055
	.2	2152	590.8	8,499	35.51	1.224	2.307	1510	24.925	34.861		369,248
	.3	2072	585.6	18,204	35.66	1.224	2.247	1515	25.011	33.176		371,255
M3	.05	2176	587.1	41,725	35.91	1.222	2.181	1517	25.084	29.665		372,639
	.1	2072	587.1	71,639	36.17	1.223	2.137	1516	25.125	26.392		372,867
	.2	2072	585.5	109,058	36.43	1.226	2.101	1514	25.156	24.078		372,477
	.3	2041	924.5	8,269	35.45	1.227	2.307	1493	24.762	34.601		364,303
M4	.05	2080	924.1	27,957	35.58	1.226	2.246	1496	24.832	32.999		366,951
	.1	2034	929.2	51,125	35.84	1.225	2.180	1497	24.891	29.629		367,146
	.2	2034	927.9	70,557	36.20	1.226	2.136	1496	24.926	26.381		367,226
	.3	2034	925.7	107,511	36.37	1.229	2.100	1494	24.954	23.973		366,736
M5	.05	2072	923.8	7,243	34.43	1.238	2.316	1222	22.567	35.077		317,631
	.1	2034	923.0	15,726	34.57	1.238	2.249	1221	22.585	33.694		317,839
	.2	2034	920.1	26,210	34.89	1.238	2.175	1218	22.624	32.592		317,850
	.3	2034	921.1	42,444	35.25	1.239	2.125	1215	22.734	27.272		317,262
M6	.05	2034	921.1	59,056	35.67	1.238	2.084	1211	22.930	24.164		316,289
	.1	2034	923.8	6,949	35.28	1.216	2.291	1544	25.639	37.039		388,675
	.2	2034	923.2	19,252	35.46	1.214	2.234	1558	25.333	34.820		393,137
	.3	2034	923.2	41,534	35.81	1.211	2.171	1570	26.034	30.279		396,735
M7	.05	2034	923.2	76,500	36.11	1.211	2.129	1575	26.143	26.483		398,114
	.1	2034	923.2	116,444	36.43	1.212	2.095	1577	26.218	24.906		398,469
	.2	2034	923.2	6,902	35.19	1.213	2.275	1573	25.911	37.541		387,431
	.3	2034	923.2	19,252	35.41	1.210	2.219	1591	25.193	35.371		392,559
M8	.05	2034	923.2	41,534	35.71	1.207	2.158	1606	26.455	30.636		396,840
	.1	2034	923.2	76,427	35.93	1.207	2.117	1613	26.599	26.707		396,898
	.2	2034	923.2	116,444	36.15	1.210	2.083	1618	26.698	25.293		399,679
	.3	2034	923.2	116,444	36.15	1.210	2.083	1618	26.698	25.293		399,679

TABLE VII
(Continued)

Variation of the Thermodynamic Properties of Military Propellants with Loading Density.

Propellant	Loading Density gm/cc	T _v °K	E cal/gm	F psi	C _v cal/gm - °K	γ	S cal/gm - °K	H _f cal/gm	N lb/mole	ln ³ /lb	P ₁ atm-lb/lb	P atm-lb/lb
ML2	.05	3019	832.7	7,947	.3499	1.235	2.297	1425	24.254	34.172	345,579	344,895
	.1	3028	833.6	16,930	.3512	1.235	2.235	1427	24.327	32.756		345,726
	.2	3034	832.5	38,916	.3517	1.235	2.167	1425	24.358	29.590		346,180
	.3	3034	829.7	66,894	.3504	1.236	2.121	1422	24.385	26.544		345,955
	.4	3029	826.5	101,893	.3593	1.239	2.084	1419	24.410	23.807		345,212
ML2	.05	2849	774.2	7,744	.3479	1.244	2.308	1342	23.574	34.336	334,697	335,320
	.1	2854	774.1	16,560	.3492	1.244	2.244	1342	23.595	32.949		336,227
	.2	2858	771.9	37,981	.3520	1.244	2.173	1340	23.624	29.917		336,590
	.3	2856	769.8	65,360	.3549	1.245	2.126	1337	23.657	26.729		335,945
	.4	2851	765.1	99,615	.3581	1.249	2.087	1335	23.708	23.529		335,083
ML4	.05	2713	725.2	7,571	.3451	1.252	2.311	1269	23.044	34.723	326,930	327,773
	.1	2722	727.7	16,201	.3464	1.252	2.246	1269	23.061	33.226		328,132
	.2	2724	725.3	37,230	.3493	1.253	2.174	1266	23.094	30.249		328,140
	.3	2722	722.0	64,191	.3524	1.257	2.125	1263	23.146	26.959		327,583
	.4	2720	716.2	97,996	.3559	1.261	2.085	1259	23.247	23.590		326,569
ML5	.05	2559	694.5	7,591	.3573	1.261	2.392	996.5	21.575	34.510	327,976	328,726
	.1	2542	693.9	15,228	.3590	1.261	2.322	995.9	21.497	33.157		328,956
	.2	2545	691.8	37,295	.3626	1.260	2.244	993.6	21.564	30.155		328,855
	.3	2548	689.3	64,261	.3666	1.260	2.192	991.3	21.700	26.912		328,177
	.4	2554	686.7	98,013	.3714	1.262	2.149	988.7	21.955	23.807		327,011
ML7	.05	2360	832.4	6,245	.3592	1.242	2.371	1151	22.934	33.193	357,160	358,367
	.1	2969	833.3	17,591	.3606	1.242	2.306	1152	22.965	31.637		359,146
	.2	2974	832.3	40,116	.3635	1.241	2.234	1151	23.003	28.915		359,483
	.3	2975	830.1	68,656	.3665	1.242	2.186	1149	23.045	25.918		359,090
	.4	2965	827.2	101,358	.3697	1.244	2.147	1146	23.098	23.184		358,167
ML8	.05	2556	694.0	7,405	.3487	1.256	2.332	1251	22.436	33.016	319,599	320,405
	.1	2549	693.1	15,555	.3502	1.256	2.264	1250	22.452	31.627		320,656
	.2	2591	690.4	36,499	.3534	1.256	2.190	1247	22.500	30.544		320,655
	.3	2592	686.3	63,041	.3570	1.258	2.140	1244	22.537	27.236		320,102
	.4	2595	682.9	96,283	.3611	1.260	2.099	1240	22.764	24.120		319,129
ML8	.05	2667	730.3	7,773	.3480	1.243	2.366	1345	23.637	34.314	355,931	356,957
	.1	2675	730.2	16,620	.3495	1.243	2.295	1346	23.659	32.925		357,506
	.2	2677	728.1	38,112	.3521	1.243	2.173	1346	23.686	29.856		357,687
	.3	2675	725.1	65,174	.3550	1.244	2.126	1343	23.721	26.702		357,252
	.4	2670	721.3	99,926	.3581	1.248	2.087	1339	23.769	23.821		356,551

TABLE VIII

Covolume Correction for Military Propellants

Propellant	$\frac{F}{\ln - \ln b}$	$\frac{a_1}{\ln^3/\ln b}$	$2a_2$	$3a_3$
M1	3,658,720	36.956	-1.8768×10^{-4}	5.7114×10^{-10}
M1A1	3,442,820	37.518	-1.9386×10^{-4}	5.5963×10^{-10}
M2	4,403,320	36.450	-1.9319×10^{-4}	7.3135×10^{-10}
M5	4,348,670	36.109	-1.8528×10^{-4}	6.7349×10^{-10}
M6	3,802,480	36.386	-1.7970×10^{-4}	5.4313×10^{-10}
M8	4,611,070	39.247	-2.5110×10^{-4}	10.9872×10^{-10}
M9	4,584,460	40.127	-2.6753×10^{-4}	12.0317×10^{-10}
M10	4,122,950	35.492	-1.7028×10^{-4}	5.4562×10^{-10}
M12	4,016,360	35.620	-1.6973×10^{-4}	5.1602×10^{-10}
M14	3,923,160	36.015	-1.7451×10^{-4}	5.2861×10^{-10}
M15	3,935,710	35.755	-1.6748×10^{-4}	4.6486×10^{-10}
M17	4,285,920	34.460	-1.5753×10^{-4}	4.8182×10^{-10}
M18	3,835,190	36.295	-1.7658×10^{-4}	5.2136×10^{-10}
IMR	4,031,170	35.603	-1.6969×10^{-4}	5.1829×10^{-10}

$$P/\Delta = F + a_1 P + a_2 P^2 + a_3 P^3$$

$$\eta = a_1 + 2a_2 P + 3a_3 P^2$$

TABLE IX

Atomic Composition and Heat of Formation of
Military and Experimental Propellants

Propellant	C	H	O	N	$\Delta H F$ cal/gm
	gm - atoms/gm :: 10^5				
M1	2535	3102	3370	894	538
M1A1	2577	3237	3357	862	574
M2	2049	2837	3669	986	559
M5	2085	2855	3655	970	568
M6	2467	3015	3412	911	538
M7	1965	2565	3683	1063	483
M8	1911	2609	3710	1075	475
M9	1844	2527	3751	1091	477
M10	2214	2854	3606	916	593
M12	2309	2922	3522	927	568
M14	2406	2940	3456	918	541
M15	1597	3532	2565	2586	302
M17	1395	3301	2718	2602	319
M18	2440	3145	3446	885	557
M26	2224	2951	3515	1006	504
DMR	2301	2912	3527	927	568
T20	1599	3690	2479	2672	323
T25	2223	2890	3532	989	521
T31	1929	2663	3697	1072	491
T32	2244	2966	3476	1032	474
T33	2230	2936	3480	1040	466
T34	1572	3524	2614	2552	331

TABLE X

Atomic Composition and Heats of Formation of Special Propellants

Propellant		C	H	O	N	ΔH_F cal/gm
		gm - atoms / gm $\times 10^5$				
M1	0-0	2534	2990	3368	905	516
M1	2-0	2568	3184	3344	887	533
M1	4-0	2602	3371	3322	870	549
M1	6-0	2635	3552	3307	854	565
M1	0-2	2484	3116	3410	887	579
M1	0-4	2437	3298	3451	870	639
M1	0-6	2391	3444	3490	854	697
M1	3-5	2513	3497	3395	854	631
5% NG	95% NC	2096	2602	3674	958	575
10% NG	90% NC	2055	2581	3689	977	564
15% NG	85% NC	2015	2560	3705	996	553
20% NG	80% NC	1974	2539	3720	1015	541

TABLE XI
Atomic Composition and Heat of Formation
of Propellant Reactants

Reactant	% N	C H O N				ΔH_f cal/gm	Source
		gm - atom/gm x 10 ⁵					
Nitrocellulose	12.2	2250	2879	3617	871	641	1
	12.6	2203	2772	3635	899	612	1
	12.8	2179	2718	3643	914	598	1
	13.0	2155	2664	3652	928	584	1
	13.1	2143	2637	3656	935	577	1
	13.25	2137	2623	3659	939	574	1*
	13.2	2131	2610	3661	942	569	1
	13.25	2125	2596	3662	946	564	1*
	13.35	2113	2564	3667	953	558	1*
Nitroglycerine		1321	2202	3963	1321	349	1
Nitroguanidine		961	3844	1922	3844	207	4
Dinitrotoluene		3843	3294	2196	1098	15	1
Dibutylphthalate		5748	7904	1437		679	1
Diphenylamine		7092	6501		591	-210	1
2-Nitrodiphenylamine		5601	4668	934	934	-136	6
Ethyl Centralite		6339	7458	373	746	55	4
Graphite		8326				0	3
Ethyl Alcohol		4343	13030	2172		1393	4
Water (1)			11101	5551		3741	5
Carbon Black		8326				0	3
Diethylphthalate		5400	6300	1800		681	2

THERMOCHEMICAL DATA SOURCE

- (1) Hunt. "Internal Ballistics", page 217, Philosophical Library, New York 1951.
- (1*) Ibid: Data obtained by interpolation.
- (2) Ibid: Heat for formation data obtained by extrapolation from those of di-
amylphthalate and dibutylphthalate.
- (3) Computed data.
- (4) Corner, J. "Theory of the Interior Ballistics of Guns", page 94, John Wiley
& Sons, Inc., New York 1950.
- (5) "Handbook of Chemistry and Physics", 38th ed., page 1698, Chemical Rubber
Publishing Company, Cleveland, Ohio, 1956.
- (6) Computed from data on structural features.

TABLE XII

Heats of Formation of Propellant Combustion Products

Product	ΔH_f at 298°K cal/mole
CO ₂	94,052
CO	26,416
H ₂	0
H ₂ O (g)	57,798
H ₂	0
O ₂	0
O	-59,159
OH	-10,060
H	-52,089
NO	-21,600
N	-85,565
NH ₃	11,040
CH ₄	17,889

TABLE XIII

Internal Energy Correction ($\Delta E_{298} + \Delta_f E_o^0$) for
Propellant Combustion Products

Product	$\Delta E_{298} + \Delta_f E_o^0$ cal/mole
CO ₂	-92,323
CO	-25,723
H ₂	1,431
H ₂ O (g)	-55,329
N ₂	1,480
O ₂	1,482
O	59,601
OH	11,514
H	52,309
NO	23,079
N	86,009
NH ₃	7,545
CH ₄	-14,166

FIG. 1.
PRESSURE-ENTROPY DIAGRAM
FOR
MI PROPELLANT

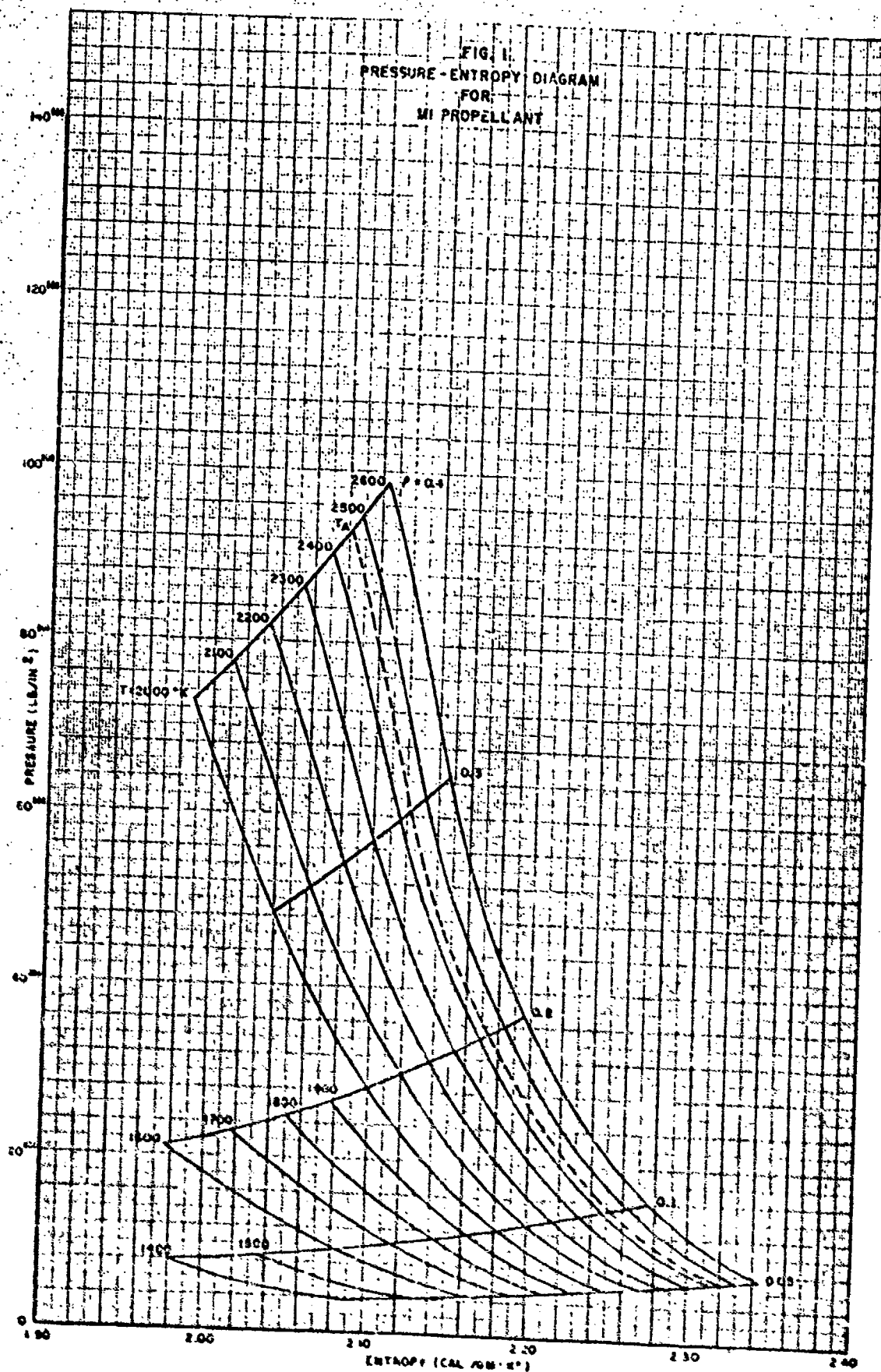
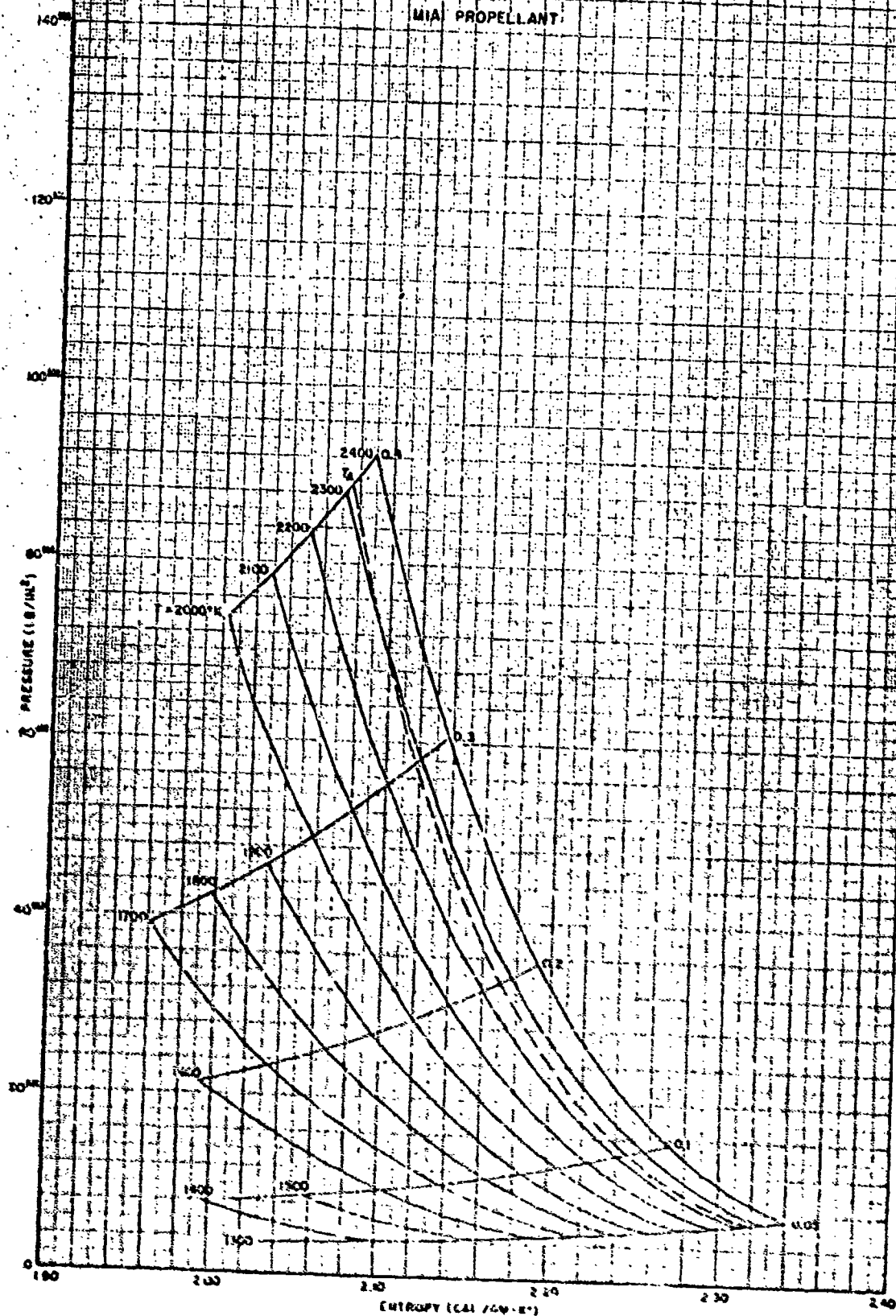
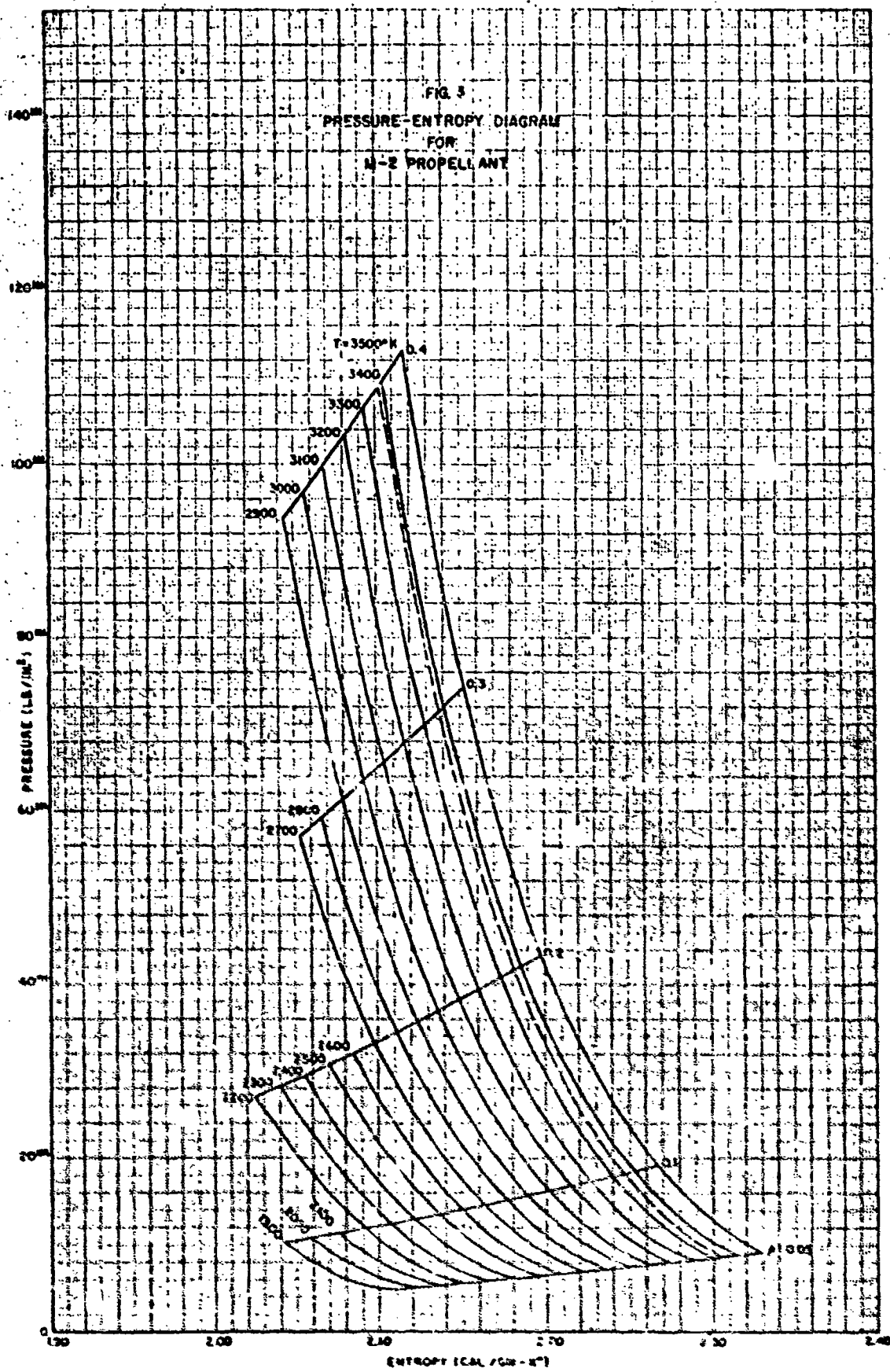


FIG. 2
PRESSURE-ENTROPY DIAGRAM
FOR
MIA PROPELLANT





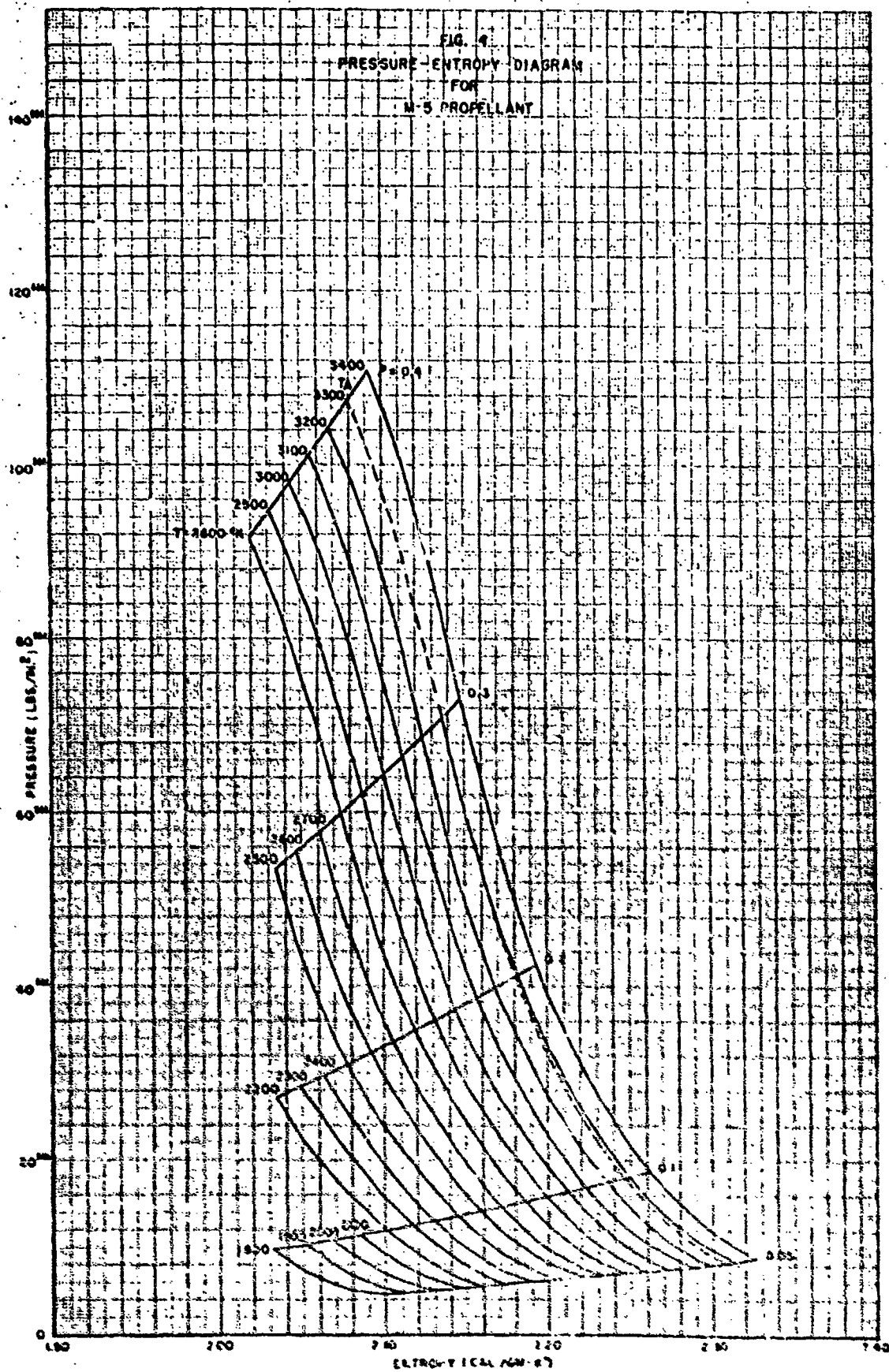


FIG. 5
PRESSURE-ENTROPY DIAGRAM
FOR
M-6 PROPELLANT

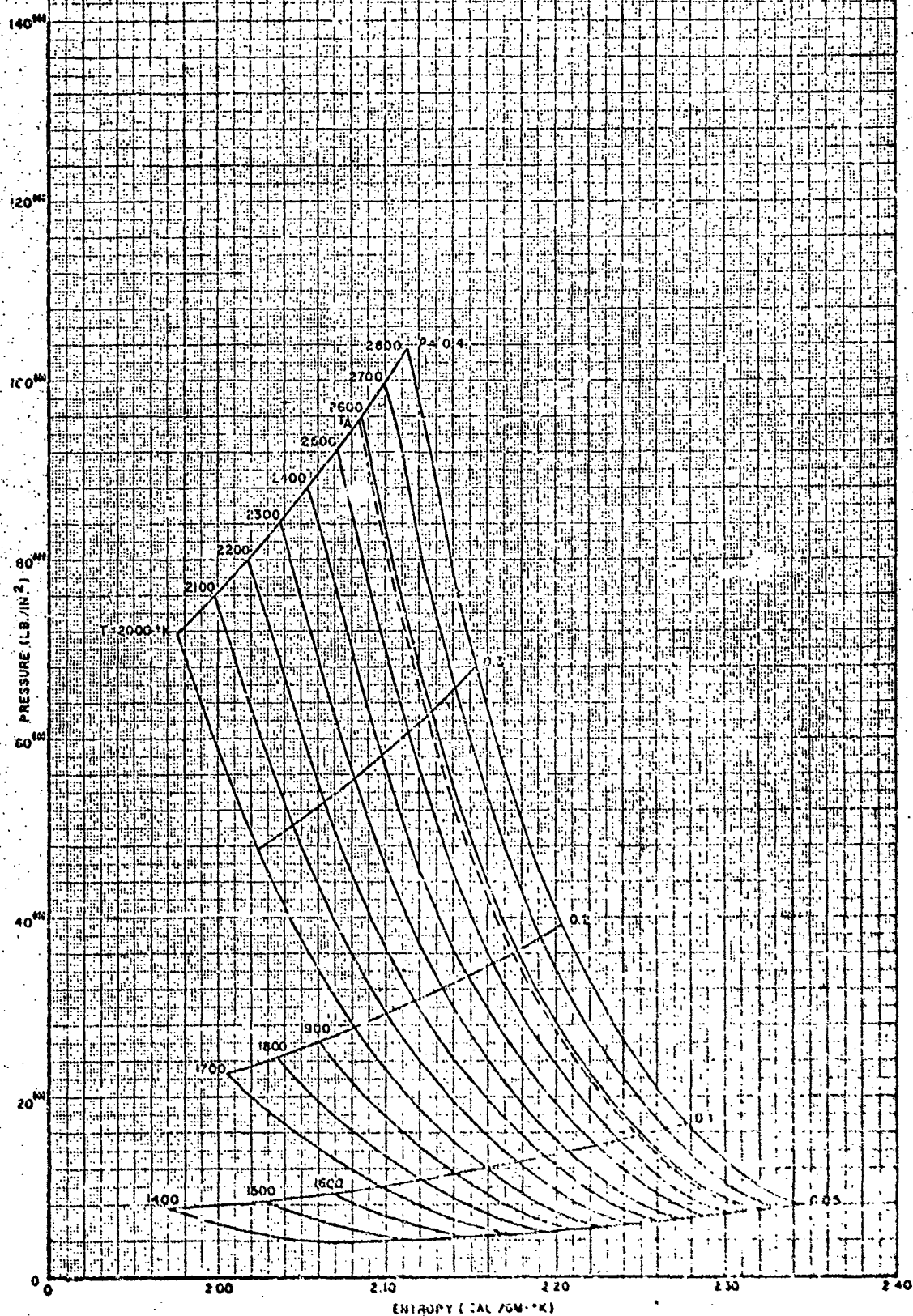


FIG 6
PRESSURE-ENTROPY DIAGRAM
FOR
M-3 PROPELLANT

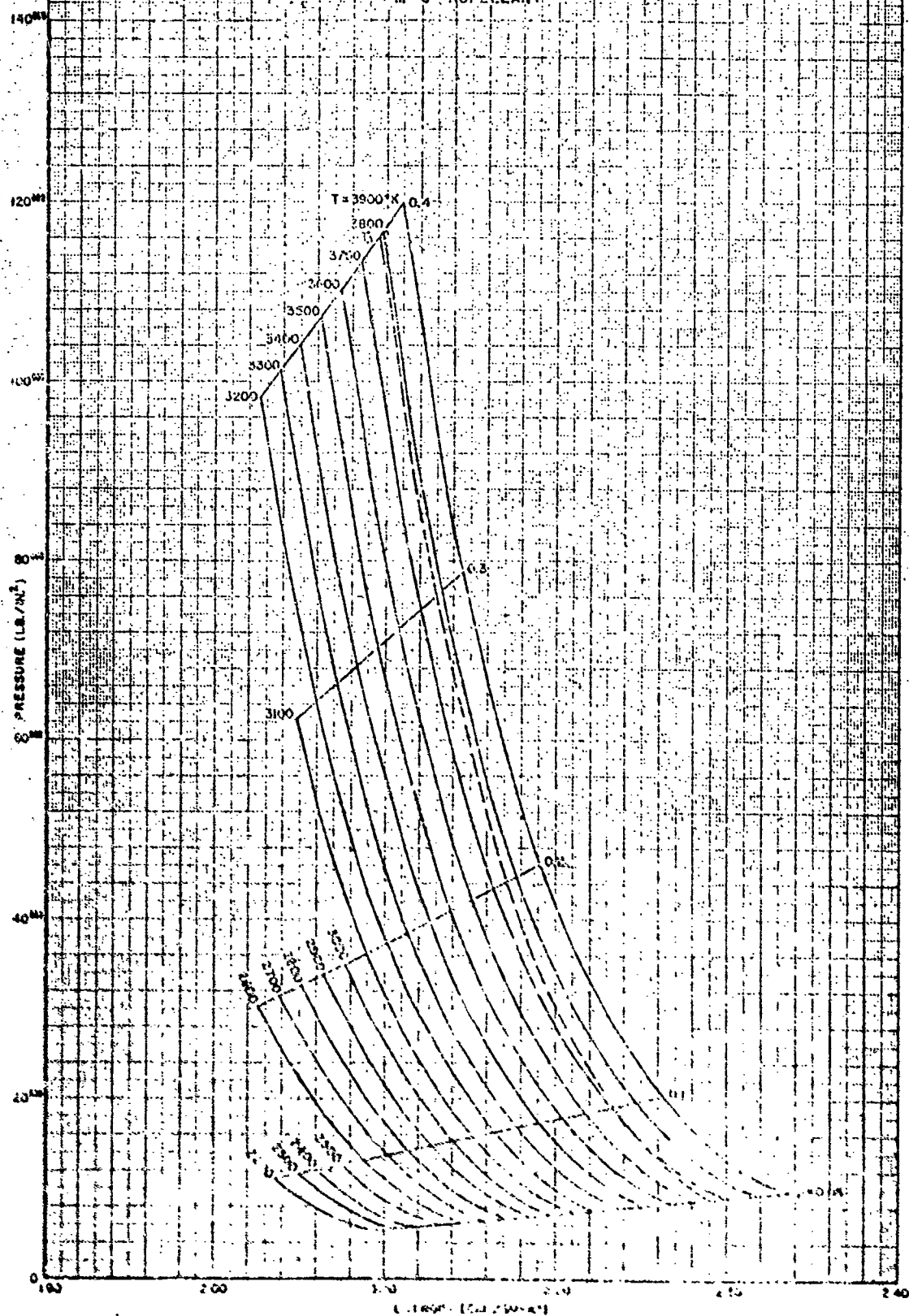


FIG. 7
PRESSURE-ENTROPY DIAGRAM
FOR
M-9 PROPELLANT

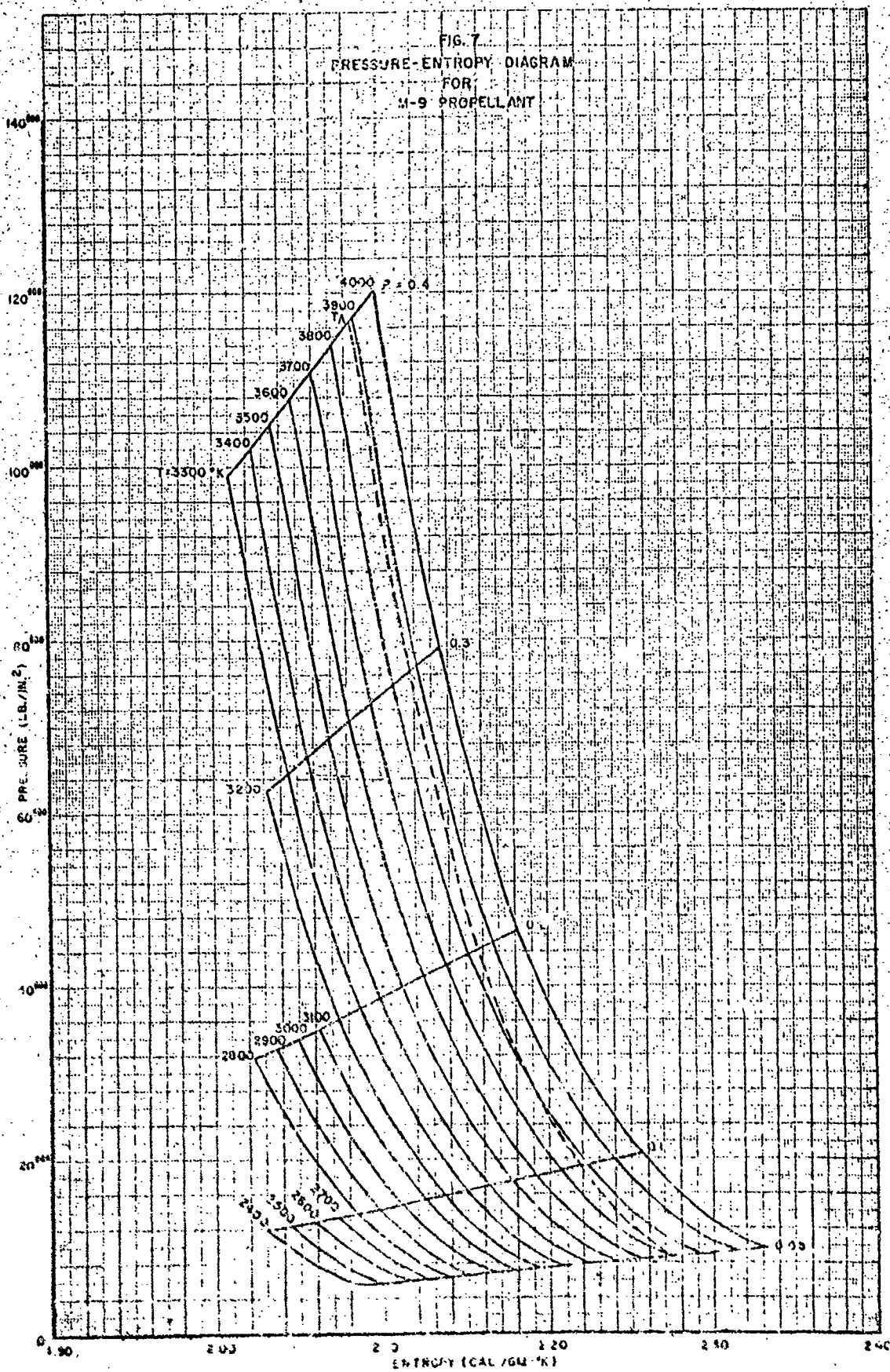


FIG. 6
PRESSURE-ENTROPY DIAGRAM
FOR
M-10 PROPELLANT

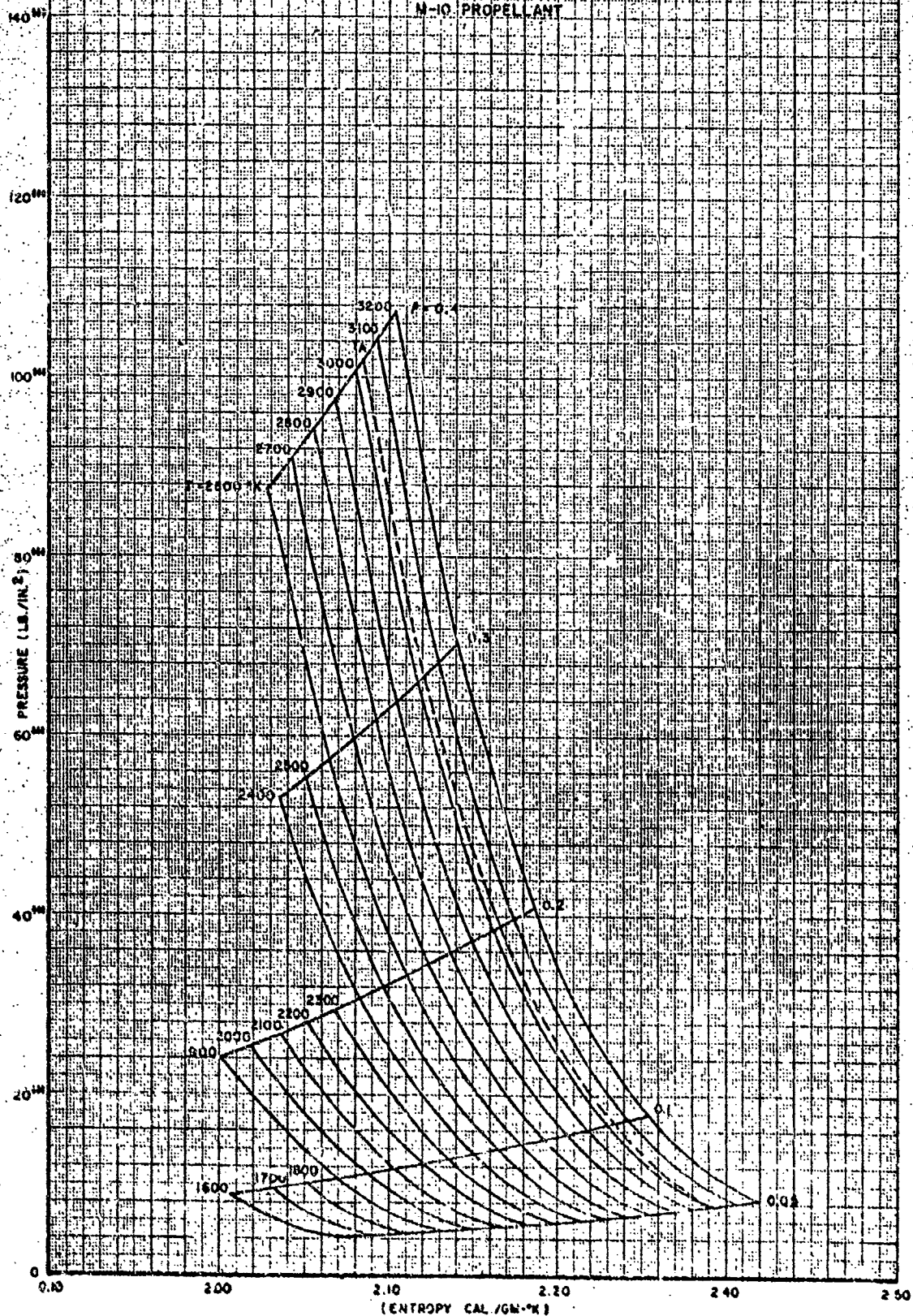


FIG 9
PRESSURE-ENTROPY DIAGRAM
FOR
M-12 PROPELLANT

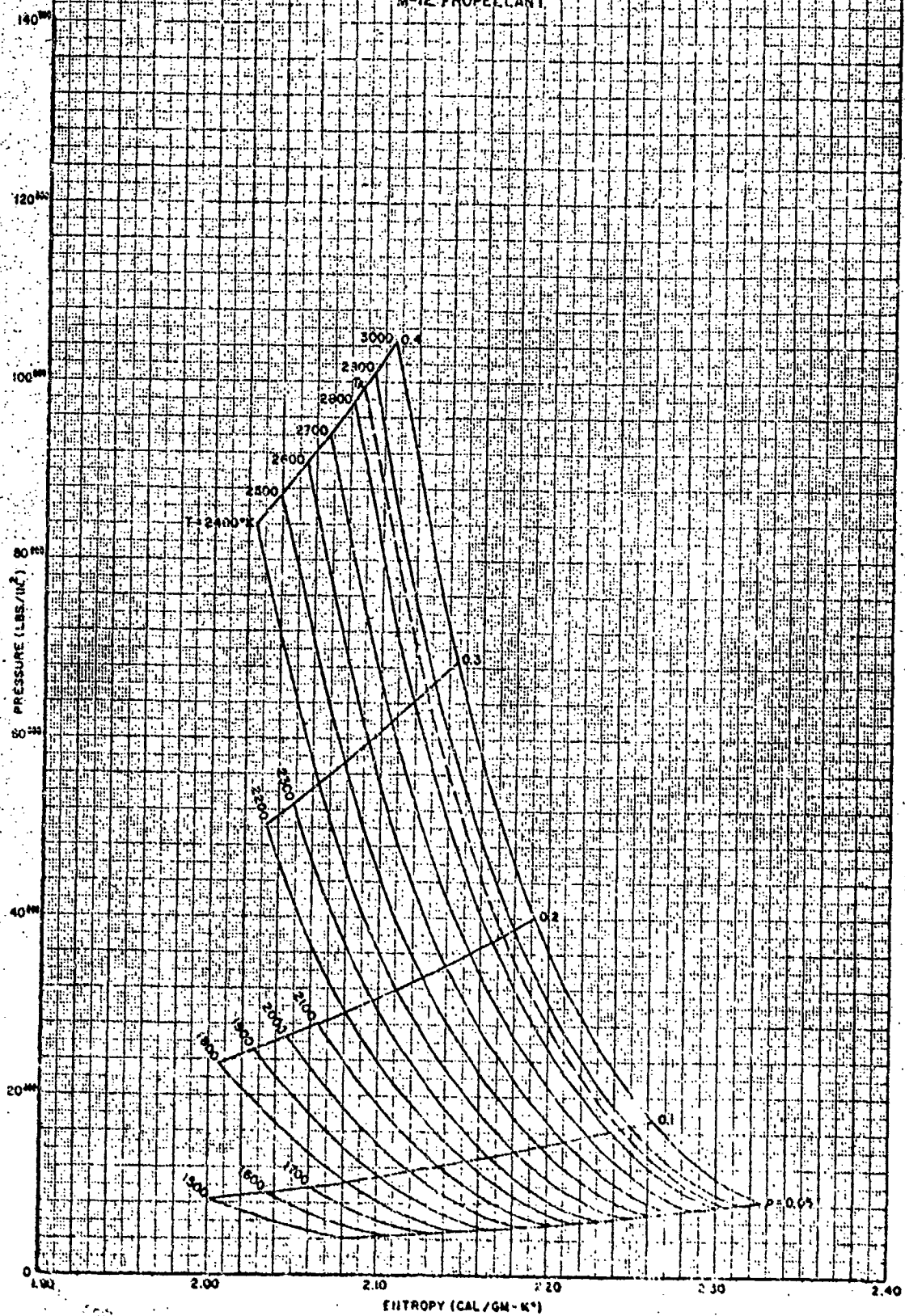


FIG. 10
PRESSURE-ENTROPY DIAGRAM
FOR
M-14 PROPELLANT

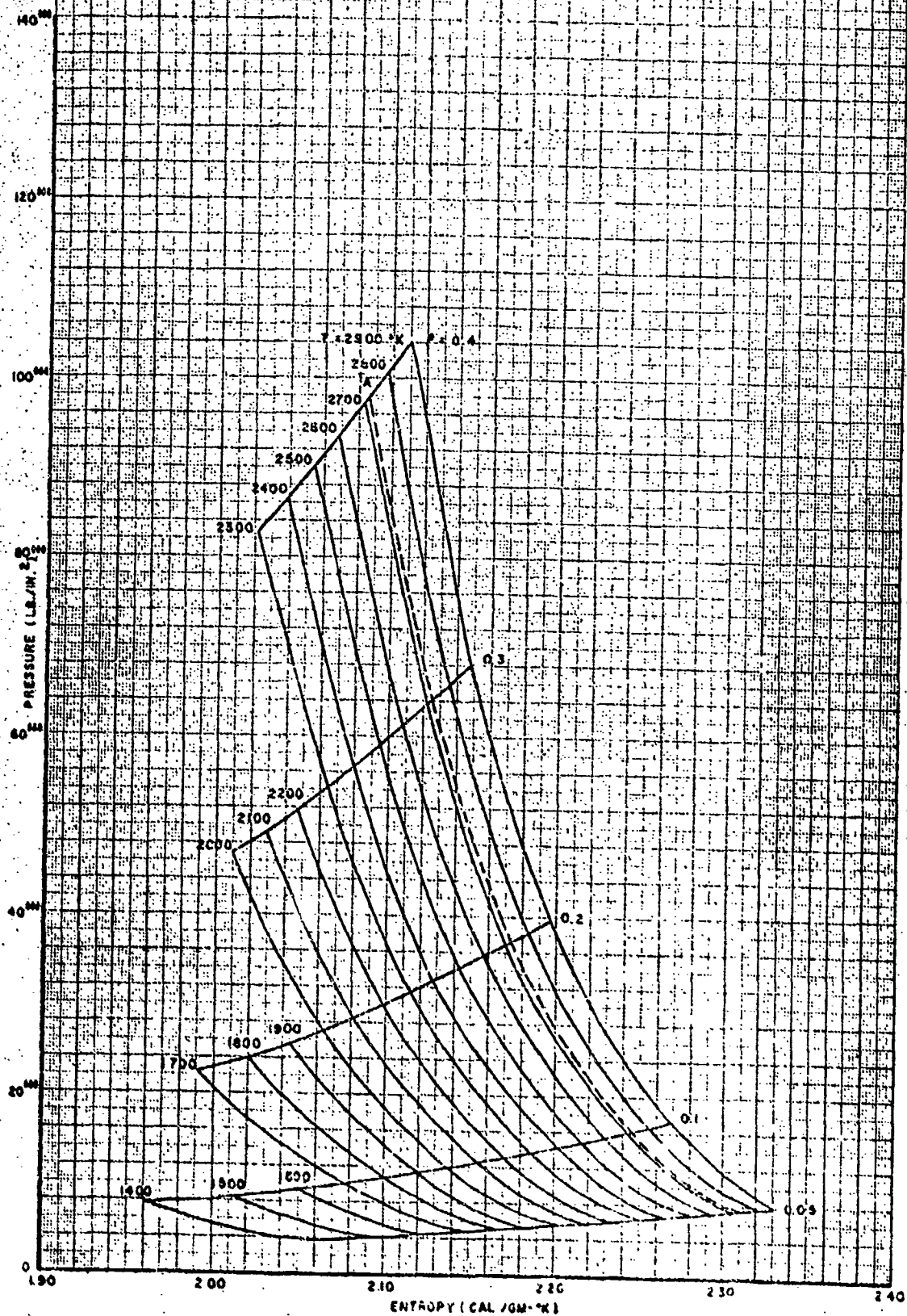


FIG. 11
PRESSURE-ENTROPY DIAGRAM
FOR
M-15 PROPELLANT

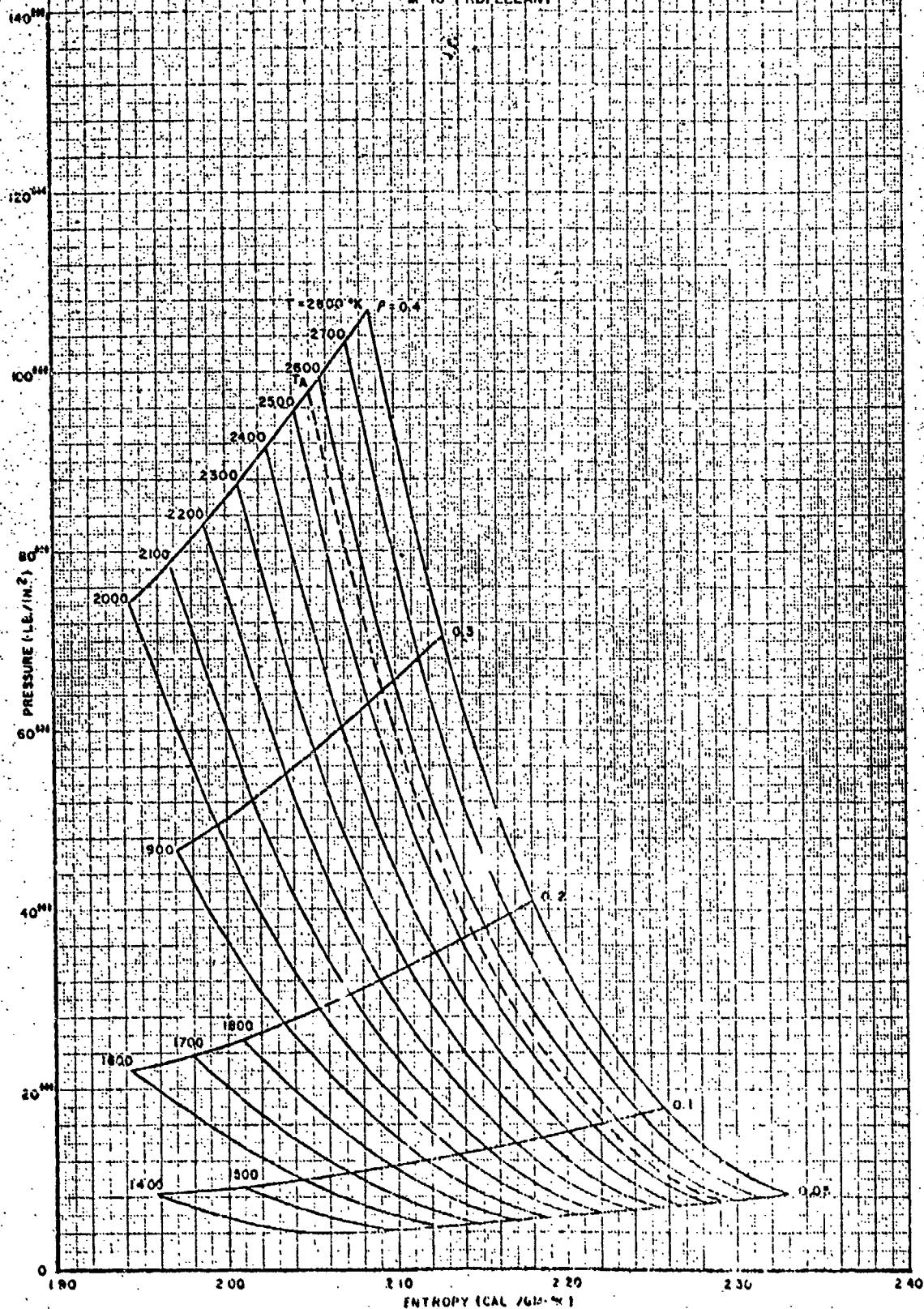
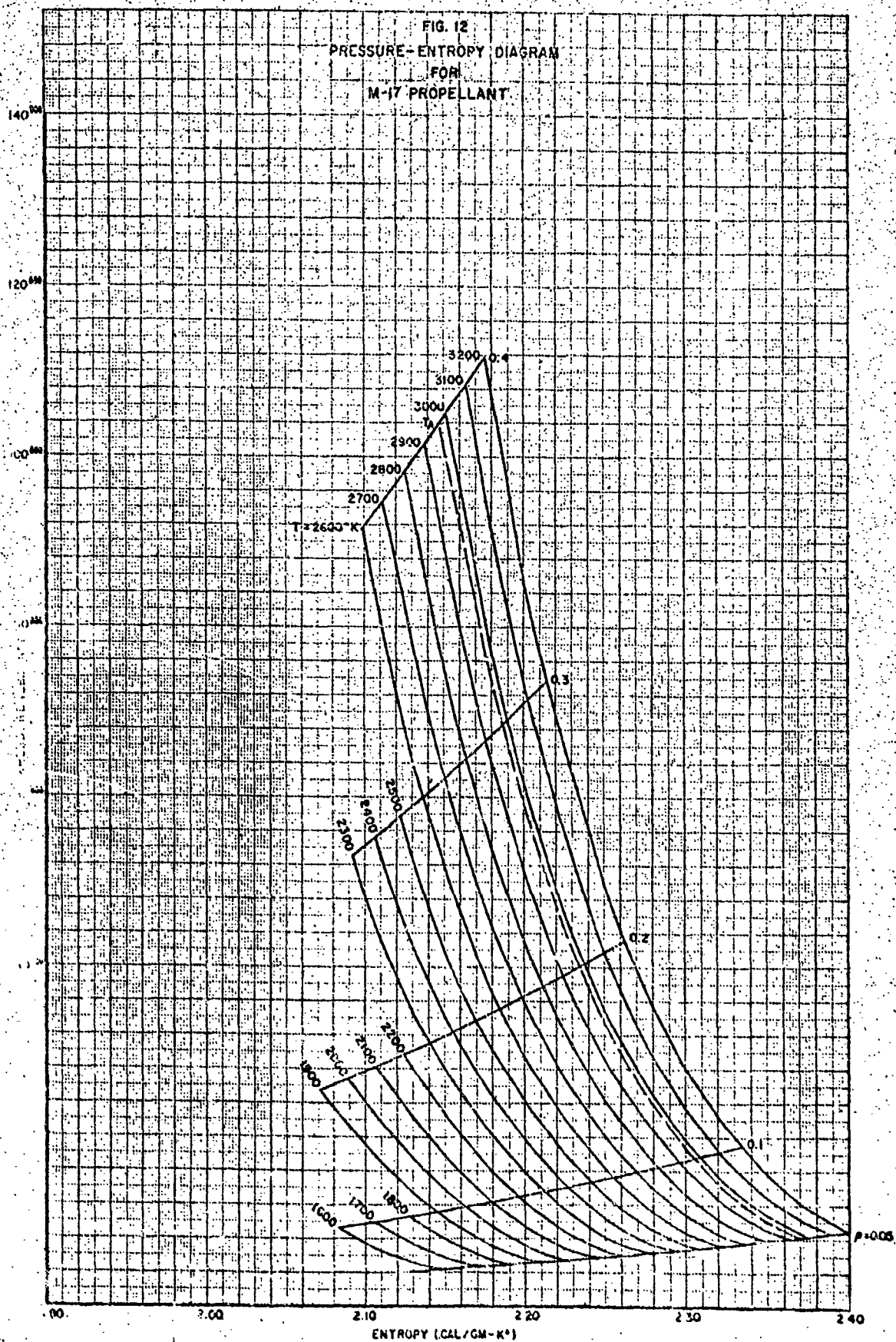


FIG. 12
PRESSURE-ENTROPY DIAGRAM
FOR
M-17 PROPELLANT



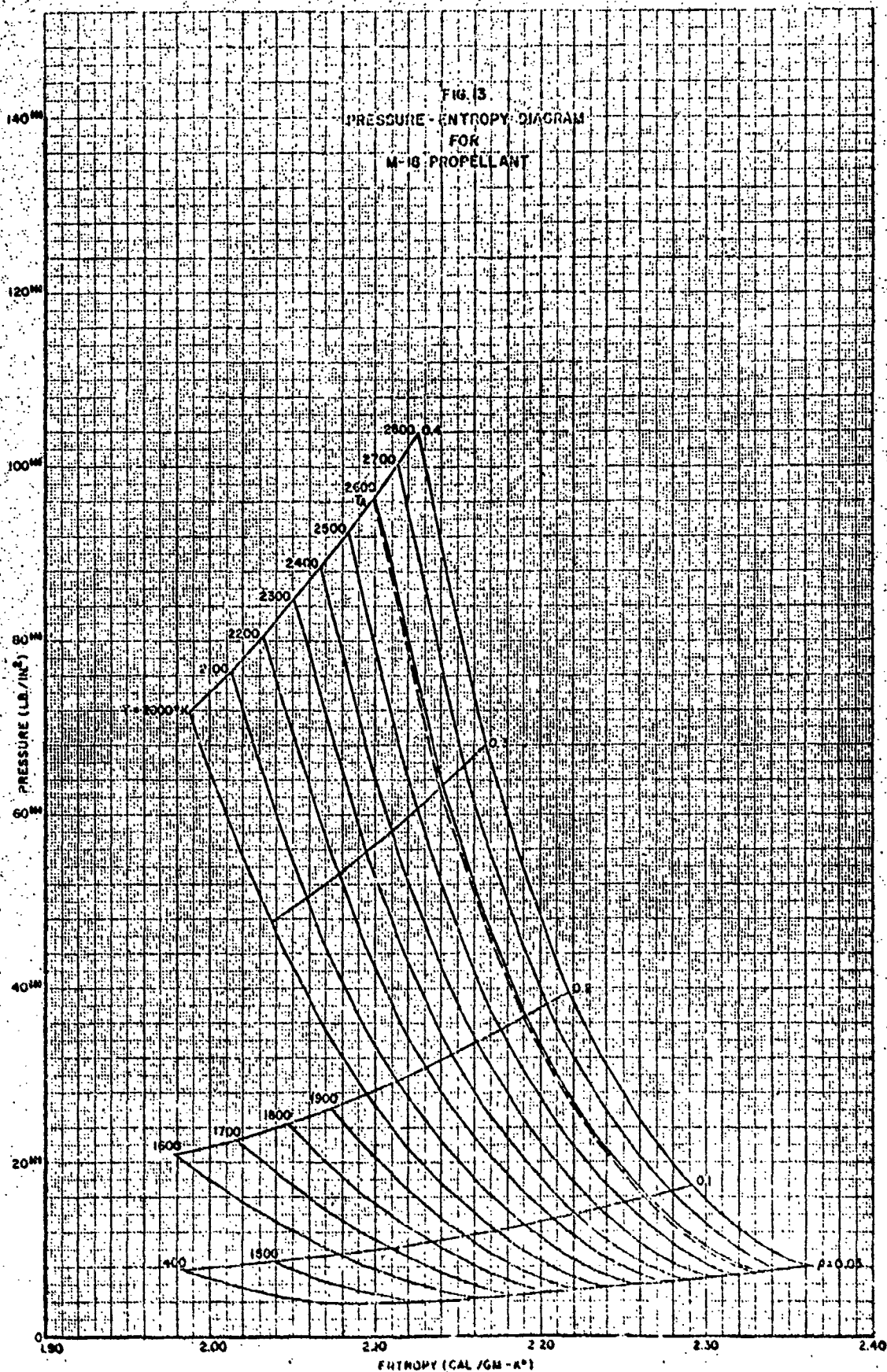
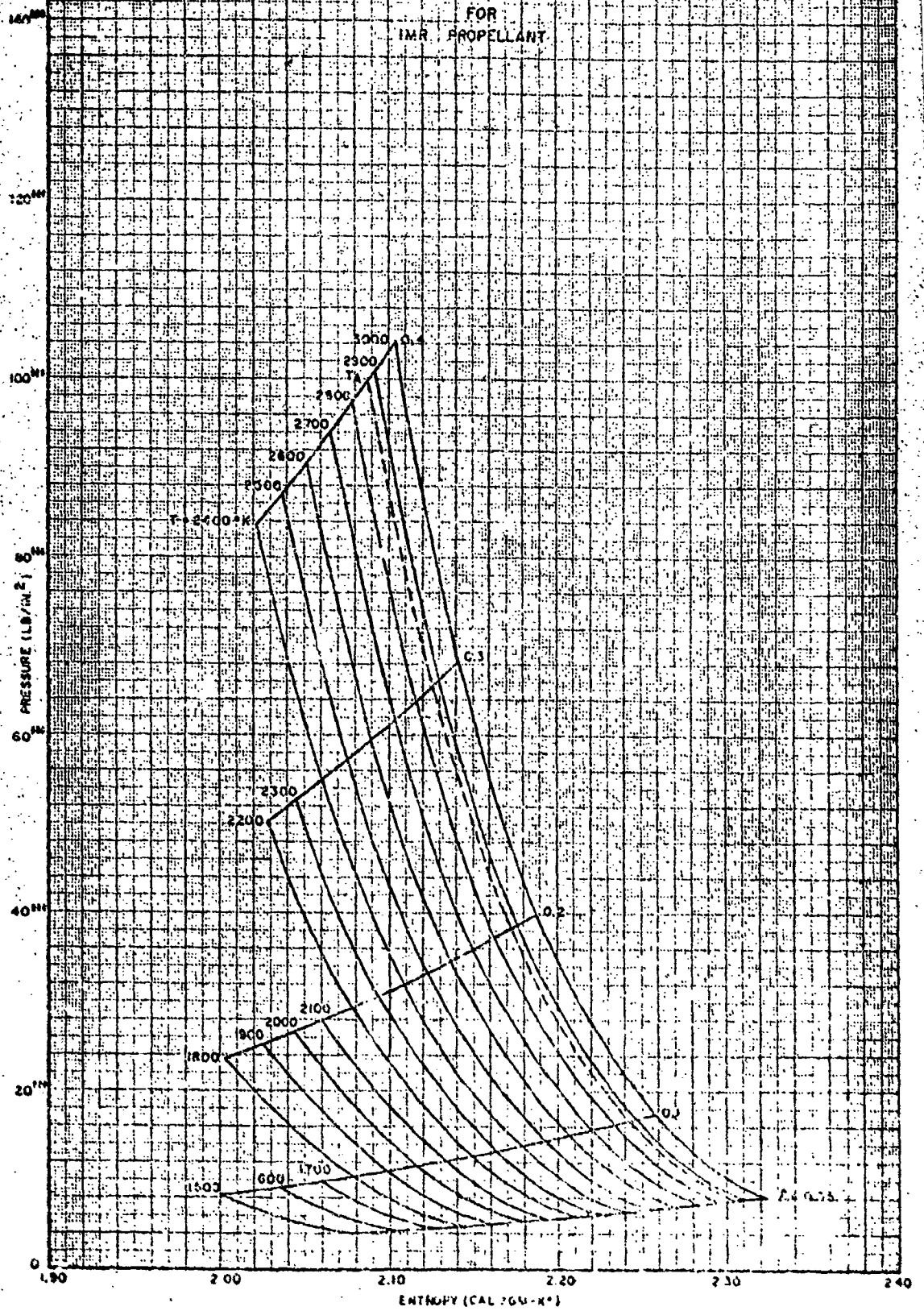


FIG. 14
PRESSURE-ENTROPY DIAGRAM
FOR
IMR PROPELLANT



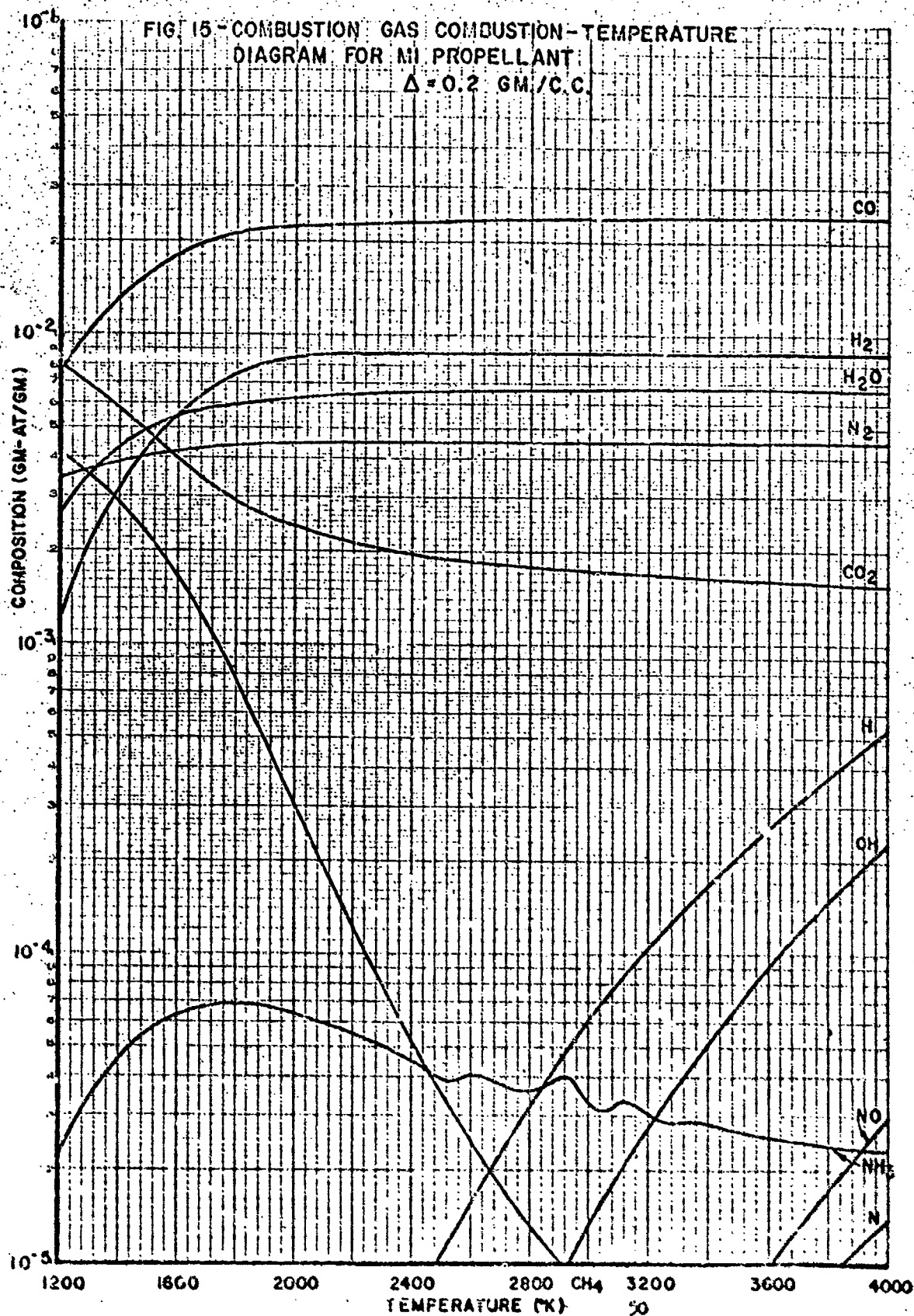
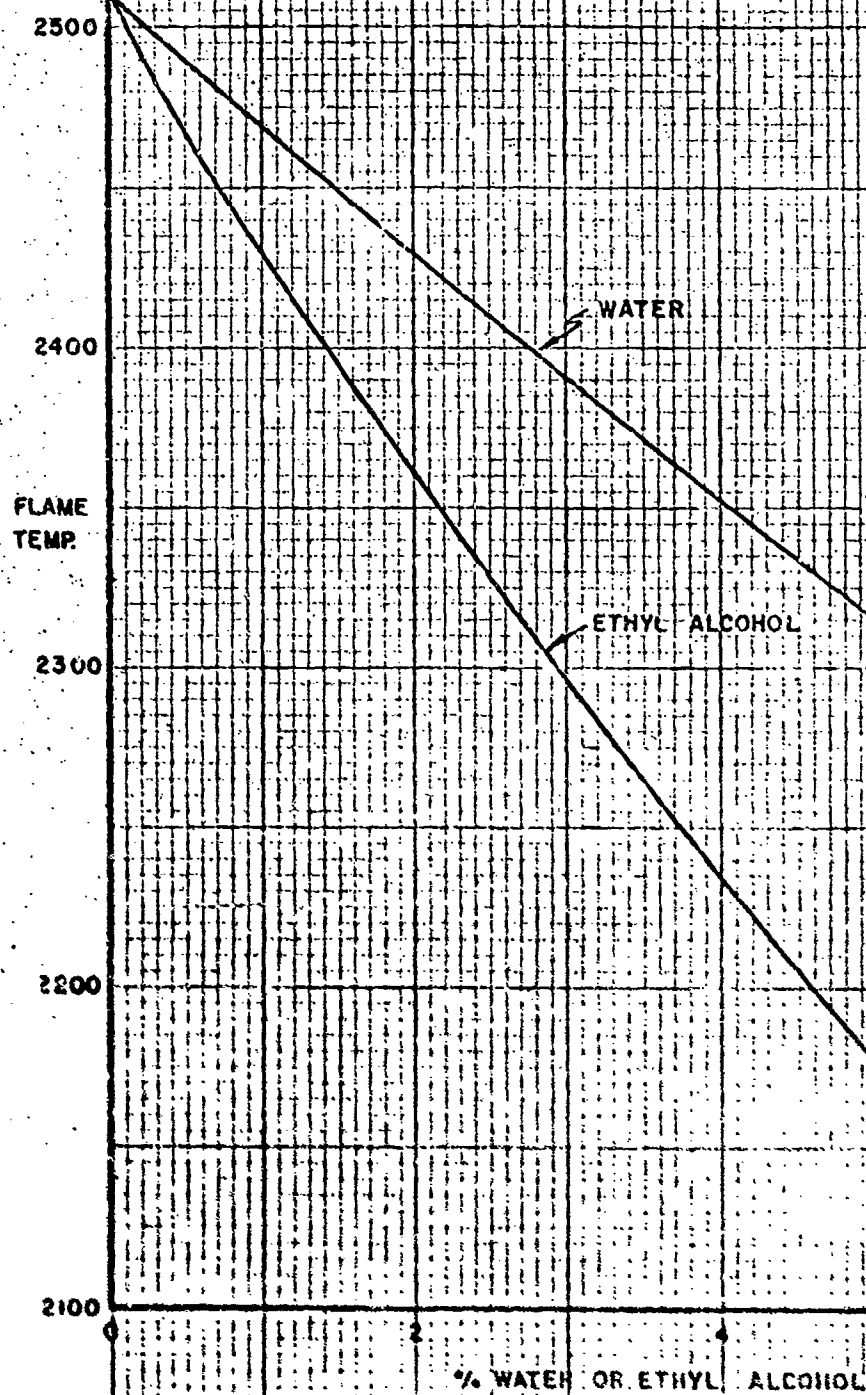


FIG. 16-VARIATION OF FLAME TEMPERATURE OF MI PROPELLANT WITH ADDED WATER OR ETHYL ALCOHOL



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	PAGE
12.6% NC	260
12.8% NC	263
13.0% NC	266
13.1% NC	269
13.15% NF	272
13.2% NC	275
0% NG 100% NC	278
5% NG 95% NC	282
10% NG 90% NC	286
15% NG 85% NC	290
20% NG 80% NC	294
NI Ideal Gas	298

USE OF TABLES

In the following tables thermodynamic properties and combustion gas composition are listed for all the propellants which appear in Tables I through IV. In the thermodynamic properties and combustion gas composition tables, the type of propellant, for instance M1, appears in the upper left of the title block. In the upper right of the title block is given the loading density (gas density); for instance, 0.05 gm/cc.

In the row following TEMP. °K are combustion gas temperatures at which the combustion gas thermodynamic properties and composition was computed. These temperatures are listed starting at a temperature considerably below the flame temperature, and increase in 100 °K intervals until a temperature is reached which is usually about 200 °K above the flame temperature. The last temperature in this listing is the flame temperature.

In the column below each temperature are the combustion gas thermodynamic properties and composition at a temperature and gas density (loading density). The thermodynamic properties are as follows:

- MOL.WT. - Average molecular weight - gm/gm - mole
- P - Pressure - psi
- E - Energy content - cal/gm
- CV - Specific heat at constant volume - cal/gm - °K
- γ - Ratio of specific heats
- S - Entropy - cal/gm - °K
- E - Internal energy - cal/gm
- HF - Heat of formation - cal/gm

The thermodynamic values are complete for all temperatures listed, except the flame temperature. In the flame temperature column the value for energy content was not computed, thus a blank space appears for this value.

Below the table of thermodynamic properties are listed the combustion gas composition. The gas species are: CO, CO₂, H₂, H₂O, N₂, O₂, O, OH, H, NO, H, NH₃, and CH₄. The units of composition are gm - moles/gm.

In the gas composition tables a number of blanks appear. The presence of blanks means that the computed concentration of a particular specie was less than 1×10^{-7} gm - moles/gm for the temperature and gas density shown.

COMPUTATION OF PROPELLANT FLAME TEMPERATURE

In Leser's report⁽³⁾ no provision was made in the code for the computation of the propellant's flame temperature. The following describes the method used in the revised code so that the flame temperature of the propellant could be computed.

In Hunt⁽⁶⁾ a method is given by which the flame temperature of a propellant may be computed. In this reference the flame temperature is defined as the temperature at which the internal energy of the combustion gases is equal to the heat of reaction of the propellant. This can be represented as:

$$\Delta H_f - E = 0 \quad (1A)$$

where:

ΔH_f = H_f prod - H_f prop. = heat of reaction of propellant

E = internal energy of combustion gas at flame temperature - cal/gm

H_f prod = heat of formation of combustion gases - cal/gm

H_f prop = heat of formation of propellant - cal/gm

The heat of formation of the propellant is given for each propellant, and as such is read into the program as a constant. The base temperature used to compute heats of formation is 25°C (298°K). For some propellants heats of formation were given at 300°K. The difference in heats of formations between the two temperatures was assumed to be negligible.

The heat of formation of the combustion gases is a function of the combustion gas composition, so it has to be computed at each trial temperature for which combustion gas composition is known. The function used is:

$$H_f \text{ prod} = \sum_{i=1}^s n_i (\Delta H_{f,i}) \quad (i = 1, 2, \dots, s) \quad (2A)$$

where: n_i = number of moles of i-th combustion product - moles/gm

$(\Delta H_f)_1$ = heat of formation of i-th combustion product-cal/mole

The heats of formation of the combustion products are given in Table XII.

In the original Brinkley code, an energy content "e" is computed which is defined as the energy of the combustion gases at temperature T, relative to the elements at 0°K. Since the internal energy of the gases "E" is defined as the amount of energy required to raise the combustion gases from some datum temperature (in this case 25°C) to some temperature T; it is apparent that a correction factor must be used to convert the compute energy content "e" to the internal energy "E". This conversion is made by means of the following relation:

$$E = e + \sum_{i=1}^S n_i (\Delta E_{298} + \Delta_f E_o^0)_i \quad (3A)$$

where: ΔE_{298} = change in internal energy of i-th combustion product from 0°K to 298°K - cal/mole

$\Delta_f E_o^0$ = heat of formation of i-th combustion product from the elements at 0°K - cal/mole

Tables of these values for all the combustion products is found in NBS Circular 500. In Table XIII, the correction factor is listed for each of the combustion products.

To determine the flame temperature, the computer program computes E, HF prod, ΔH_f , and $\Delta H_f - E$ for a temperature range which has been previously chosen so as to be several hundred of degrees above and below the estimated flame temperature - upon completion of this portion of the problem, the computer checks back until it reaches a set of temperatures in which the difference $\Delta H_f - E$ has changed from a positive value to a negative value. Using a 3 point Lagrangian interpolation formula on values of the difference at three temperature steps; two of which are positive and one negative, a temperature value is found in which this

difference is zero. This temperature is the flame temperature. In addition, the interpolation ratio are used to compute thermodynamic and gas composition values at the flame temperature. When this portion of the program is completed, the values are printed out and the program is stopped.

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.05

M1

TEMP. °K	1400.00	1500.00	1600.00	1700.00	1800.00	1900.00	2000.00
MOL. WT.	24.9128	23.3860	22.6442	22.3219	22.1874	22.1288	22.1016
P	3820	4232	4592	4919	5227	5528	5825
e	- 905.10	- 833.26	- 780.16	- 737.89	- 700.54	- 665.09	- 630.36
CV	.321872	.322073	.323716	.326174	.328913	.331561	.334139
γ	1.27553	1.28220	1.28376	1.28238	1.27980	1.27702	1.27429
S	2.08456	2.13417	2.16849	2.19414	2.21549	2.23465	2.25245
E	231.75	299.87	349.32	389.24	424.72	458.69	492.19
HF	1190.19	1187.34	1184.35	1182.00	1180.21	1178.76	1177.56
CO	.0180938	.0201852	.0213654	.0219844	.0223258	.0225413	.0226927
CO2	.0045150	.0038149	.0033761	.0030934	.0028944	.0027410	.0026178
H2	.0074627	.0068747	.0065770	.0063187	.0060438	.0057986	.0055703
H2O	.0045860	.0049135	.0051426	.0053282	.0054862	.0056221	.0057376
N2	.0041937	.0043289	.0044008	.0044341	.0044489	.0044560	.0044596
O2							
O							
OH							
H							
NO			.0000001	.0000002	.0000004	.0000009	.0000001
N							
NH3	.0000246	.0000244	.0000218	.0000187	.0000159	.0000136	.0000116
CH4	.0012441	.0006191	.0002777	.0001213	.0000552	.0000266	.0000139

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M1

0.05

TEMP. °K	2100.00	2200.00	2300.00	2400.00	2500.00	2600.00	2424.76
MOL. WT.	22.0875	22.0791	22.0726	22.0658	22.0597	22.0525	22.0652
P	6120	6414	6707	7001	7294	7587	7073
e	- 595.80	- 561.19	- 526.51	- 491.67	- 456.34	- 420.78	
CV	.336594	.338841	.340885	.342911	.344663	.346327	.343371
γ	1.27166	1.26924	1.26725	1.26526	1.26353	1.26192	1.26481
S	2.26931	2.28540	2.30062	2.31503	2.33008	2.34402	2.31868
E	525.70	559.34	593.12	627.22	661.42	695.90	635.68
HF	1175.51	1175.56	1174.65	1173.92	1172.80	1171.73	1173.68
CO	.0228101	.0229059	.0229876	.0230397	.0231202	.0231747	.0230079
CO2	.0025147	.0024268	.0023506	.0023028	.0022271	.0021771	.0022867
H2	.0056293	.0055528	.0054828	.0054371	.0053650	.0053193	.0054215
H2O	.0058371	.0059233	.0059984	.0060456	.0061207	.0061696	.0062016
N2	.0044617	.0044631	.0044642	.0044651	.0044654	.0044659	.0044654
O2							
O							
OH	.0000002	.0000004	.0000008	.0000015	.0000028	.0000047	.0000013
H	.0000032	.0000057	.0000095	.0000152	.0000235	.0000351	.0000170
H2O				.0000001	.0000001	.0000003	.0000001
N						.0000001	.0000001
NH3	.0000104	.0000094	.0000085	.0000078	.0000065	.0000067	.0000075
CH4	.0000078	.0000047	.0000028	.0000019	.0000012	.0000009	.0000017

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

		M1						O.1					
TEMP. °K		1400.00	1500.00	1600.00	1700.00	1800.00	1900.00	2000.00					
MOL. WT.		27.4087	25.2166	23.8163	22.9919	22.5506	22.3261	22.2149					
P		7762	8696	9567	10365	11097	11784	12444					
e		- 962.68	- 879.17	- 811.15	- 756.29	- 710.90	- 671.00	- 633.99					
CV		.329428	.328576	.328713	.329800	.331624	.333703	.336014					
γ		1.26679	1.27510	1.27982	1.28128	1.28034	1.27824	1.27560					
S		1.98580	2.03840	2.08236	2.11564	2.14159	2.16316	2.18213					
Z		171.36	253.45	318.55	370.49	413.56	451.70	487.40					
HF		1185.93	1185.75	1183.65	1181.23	1179.18	1177.57	1176.33					
CO		.0156101	.0181758	.0200387	.0212588	.0219889	.0224181	.0226754					
CO2		.0050579	.0041828	.0035589	.0031364	.0028557	.0026008	.0025203					
H2		.0052114	.0067711	.0079959	.0087912	.0092068	.0093786	.0094220					
H2O		.0045055	.0049767	.0052750	.0054761	.0056289	.0057557	.0058640					
H2		.0039929	.0041613	.0042821	.0043596	.0044040	.0044280	.0044409					
O2													
OH													
H													
NO													
N													
NH3		.0000341	.0000386	.0000393	.0000372	.0000337	.0000299	.0000263					
CH4		.0020728	.0013501	.0007982	.0004341	.0002265	.0001179	.0000640					

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

MI

0.1

TEMP. °K	2100.00	2200.00	2300.00	2400.00	2500.00	2600.00	2427.84
MOL. WT.	22.1572	22.1257	22.1056	22.0929	22.0809	22.0733	22.0895
P	13090	13729	14361	14991	15619	16247	15166
e	- 598.20	- 562.89	- 527.84	- 492.81	- 457.38	- 421.86	
CV	.338369	.340524	.342468	.344481	.346202	.347812	.344990
γ	1.27272	1.26998	1.26783	1.26553	1.26352	1.26163	1.26494
S	2.19959	2.21599	2.23158	2.24588	2.26097	2.27491	2.25000
E	522.12	556.50	590.71	625.11	659.56	694.20	634.70
HF	1175.29	1174.39	1173.56	1172.93	1171.97	1171.09	1172.70
CO	.0228459	.0229683	.0230652	.0231248	.0232092	.0232642	.0231458
CO2	.0024103	.0023202	.0022434	.0021956	.0021211	.0020723	.0021776
H2	.0094082	.0093691	.0093230	.0092917	.0092302	.0091840	.0092777
H2O	.0059572	.0060386	.0061104	.0061554	.0062283	.0062753	.0061729
H2	.0044481	.0044525	.0044554	.0044575	.0044601	.0044605	.0044582
O2							
O							
OH	.0000001	.0000003	.0000006	.0000011	.0000019	.0000033	.0000013
H	.0000022	.0000039	.0000065	.0000105	.0000162	.0000241	.0000119
NO						.0000002	.0000001
N						.0000001	.0000001
NH3	.0000235	.0000212	.0000193	.0000176	.0000147	.0000153	.0000170
CH4	.0000365	.0000221	.0000136	.0000090	.0000060	.0000042	.0000080

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M1

0.2

TEMP. °K	1600.00	1700.00	1800.00	1900.00	2000.00	2100.00	2200.00
MOL. WT.	26.0921	24.7193	23.7653	23.1294	22.7350	22.4956	22.3533
P	21040	23028	24925	26717	28401	30005	31552
e	- 866.13	- 799.78	- 742.23	- 691.84	- 647.56	- 606.67	- 568.47
Cv	335003	327523	320305	313247	306349	300053	294553
γ	1.27251	1.27529	1.27640	1.27651	1.27488	1.27245	1.26980
S	1.97687	2.01711	2.05001	2.07717	2.09993	2.11973	2.13760
E	260.79	325.15	380.47	428.72	471.49	510.93	548.33
HF	1179.54	1178.34	1176.63	1175.02	1173.67	1172.56	1171.65
CO	.0177594	.0194573	.0207807	.0217003	.0223046	.0226598	.0229576
CO2	.0039037	.0033095	.0028795	.0025726	.0023638	.0022143	.0021038
H2	.0034587	.00365253	.0073867	.0060166	.0054192	.0049532	.0045742
H2O	.0054180	.0057264	.0059266	.0060541	.0061616	.0062414	.0063105
N2	.0040783	.0041885	.0042720	.0043317	.0043715	.0043970	.0044133
O2							
O							
OH							
H	.0000001	.0000001	.0000002	.0000004	.0000007	.0000014	.0000002
HO							
H							
H3	.0000631	.0000678	.0000688	.0000668	.0000628	.0000584	.0000539
CH4	.0016445	.0011468	.0007618	.0004825	.0003005	.0001876	.0001200

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M1 0.2

TEMP. °K	2300.00	2400.00	2500.00	2600.00	2433.47
MOL. WT.	22.2603	22.2060	22.1634	22.1703	22.1904
P	33052	34529	35989	37423	35019
e	- 531.45	- 495.19	- 458.89	- 477.41	
CV	346176	348074	349666	349689	348641
γ	1.26780	1.26527	1.26301	1.26295	1.26448
β	2.15407	2.16889	2.16434	2.18076	2.17399
E	584.49	620.17	555.65	637.14	632.07
HF	1170.85	1170.31	1169.52	1169.52	1170.07
CO	.0231429	.0232518	.0233686	.0233604	.0232900
CO2	.0020151	.0019617	.0018860	.0018875	.0019389
H2	.0088376	.0088716	.0088627	.0088529	.0088734
H2O	.0063724	.0064109	.0064771	.0064770	.0064300
H	.0044247	.0044320	.0044359	.0044385	.0044346
O					
OH	.0000004	.0000007	.0000013	.0000013	.0000009
H	.0000042	.0000068	.0000106	.0000104	.0000080
NO			.0000001	.0000001	
N					
NH3	.0000498	.0000459	.0000386	.0000401	.0000439
CH4	.0000761	.0000514	.0000345	.0000372	.0000449

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M1		0.3					
TEMP. °K		2000.00	2100.00	2200.00	2300.00	2400.00	2500.00 2600.00
MOLE WT.							
C		23.6512	23.1453	22.6348	22.6075	22.4654	22.3533 22.2917
H		48300	51331	54177	56911	59560	62157 64688
CV		- 668.03	- 621.76	- 578.86	- 538.32	- 499.62	- 461.43 - 424.12
γ		1.34012	1.348321	1.349539	1.350805	1.352446	1.353788 1.355014
E		1.27322	1.27147	1.26944	1.26804	1.26573	1.26359 1.26141
HF		2.03937	2.06185	2.08177	2.09982	2.11568	2.13191 2.14656
		448.38	493.32	535.12	574.72	612.30	650.26 686.84
		1170.50	1169.44	1168.54	1167.73	1167.21	1166.54 1165.34
CO		.0215689	.0222144	.0226715	.0230184	.0232333	.0234292 .0235475
CO2		.0322016	.0320605	.0319128	.0317966	.0317267	.0316418 .0315834
H2		.0370369	.0374796	.0378097	.0380525	.0382101	.0383355 .0384498
H2O		.0064523	.0065028	.0066240	.006753	.0067050	.0067621 .0067939
O2		.0042090	.0043123	.0043438	.0043631	.0043347	.0043023 .004266
OH							
H		.0000001	.0000001	.0000002	.0000003	.0000006	.0000010 .0000016
HO		.0000000	.0000010	.0000018	.0000031	.0000050	.0000078 .0000117
H							.0000001 .0000001
H2O		.0001045	.0001027	.0000989	.0000943	.0000889	.0000760 .0000754
CH4		.0006738	.0004720	.0003303	.0002245	.0001586	.0001105 .0000793

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

MI 0.3

TEMP. °K 2442.89

MOL. WT.
P 22.4138
60680
CV .353058
7 1.26479
S 2.12259
E 628.94
HF 1166.94

CO .0233156
CO2 .0016921
H2 .0082584
H2O .0067262
N2 .0043921
O2

O .0000008
OH .5000061
H

NO .0000008
N .5000061
NH3 .0000843
CH4 .0001358

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M1

0.4

TEMP. °K	2000.00	2100.00	2200.00	2300.00	2400.00	2500.00	2600.00
MOL. WT.	24.6242	24.0172	23.5613	23.1899	22.9343	22.7189	22.5871
P	72824	77477	81992	86372	90593	94745	98723
C	- 640.36	- 640.36	- 393.71	- 549.46	- 507.69	- 466.75	- 427.30
CV	553171	354577	355412	356374	357713	358721	359020
Y	1.37515	1.27154	1.26994	1.26928	1.26718	1.26542	1.26346
Z	1.58761	2.01196	2.03363	2.05355	2.07050	2.08784	2.10333
L	422.73	471.51	517.14	560.43	601.57	641.64	680.42
MF	1166.57	1160.73	1164.90	1164.23	1163.75	1162.22	1162.51
CO	0.007222	0.013200	0.021334	0.026418	0.029876	0.032391	0.035003
CO2	0.021947	0.019465	0.017620	0.016131	0.015190	0.014179	0.013550
H2	0.055353	0.061311	0.065631	0.069630	0.073583	0.077423	0.081239
H2O	0.067803	0.068618	0.069493	0.070382	0.071218	0.072098	0.072989
N2	0.041569	0.042078	0.042487	0.042856	0.043199	0.043595	0.043941
O2							
OH							
H	0.000004	0.000001	0.000001	0.000003	0.000005	0.000009	0.000013
HO							
NO							
NO2							
CH4	0.001473	0.001517	0.001526	0.001517	0.001473	0.001295	0.001181
C2H4	0.0010723	0.0008264	0.0006324	0.0004682	0.0003532	0.0002611	0.0001943

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M1 0.4

TEMP. °K 2459.04

MOL. WT.
 P 22.8025
 e 93055
 CV 352347
 γ 1.26612
 S 2.08072
 E 625.44
 HF 1163.44

CO .0231755
 CO2 .0014605
 H2 .0074040
 H2O .0076473
 N2 .0043270

OH .0000007
 H .0000049

N .0001387
 NH3 .0002962

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M1A1

0.05

TEMP. °K	1300.00	1400.00	1500.00	1600.00	1700.00	1800.00	1900.00
MO. WT.	27.5059	24.8770	23.2038	22.3473	21.9495	21.7764	21.6993
P	34.06	3865	4295	4674	5016	5356	5645
C	- 984.55	- 889.90	- 813.00	- 756.67	- 711.83	- 673.03	- 636.73
CV	320955	326237	325984	327347	326628	325300	324942
Y	1.26507	1.27485	1.28256	1.28514	1.28442	1.28217	1.27952
Z	2.03173	2.15179	2.15442	2.15126	2.12347	2.24065	2.26020
E	132.50	225.27	290.98	349.89	391.81	428.58	463.35
HF	1167.44	1108.66	1105.15	1161.58	1156.92	1157.00	1155.54

CO	3432472	3122864	3205411	3213773	3225965	3229262	3232212
CO2	3032800	3242832	3035607	3031025	3028107	3026109	3024608
H2	3057262	3077070	3093114	3132206	3106038	3107266	3106929
H2O	3039514	3044584	3047342	3049328	3050952	3052371	3053617
O2	3035094	3140347	3041464	3042209	3042667	3042851	3042939

OH							
H							
NO							
N2							
CH3	3000225	3000255	3000259	3000237	3000206	3000177	3000153
CH4	3023170	3014511	3007675	3003643	3001655	3000770	3000371

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M1A1

0.05

TEMP. °K	2000.00	2100.00	2200.00	2300.00	2400.00	2236.97
MOL. WT.	21.6633	21.6448	21.6341	21.6262	21.6197	21.6308
P	5949	6252	6533	6852	7152	6664
e	- 501.47	- 566.47	- 531.47	- 496.42	- 461.21	
CV	.337542	.340032	.342320	.344410	.346475	.343115
γ	1.27683	1.27420	1.27177	1.26976	1.26775	1.27098
γ	2.27835	2.29542	2.31169	2.32728	2.34162	2.31753
E	497.43	531.40	565.47	599.65	634.14	578.10
HF	1154.36	1153.34	1152.42	1151.35	1150.84	1152.10
CO	.0233787	.0234965	.0235904	.0236694	.0237195	.0236214
CO2	.0023424	.0022443	.0021613	.0020896	.0020447	.0021335
H2	.0106376	.0105707	.0105036	.0104410	.0104000	.0104799
H2O	.0054686	.0055612	.0056416	.0057116	.0057557	.0056687
N2	.0042935	.0043011	.0043027	.0043040	.0043050	.0043033
O2						
O						
OH	.0000001	.0000002	.0000004	.0000007	.0000014	.0000005
H	.0000018	.0000034	.0000059	.0000100	.0000160	.0000073
HO					.0000001	
CH3	.0000135	.0000118	.0000106	.0000097	.0000088	.0000102
CH4	.0000199	.0000112	.0000067	.0000041	.0000027	.0000056

40

71

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.1

WIAL

TEMP. °K 2100.00 2200.00 2300.00 2400.00 2241.94

MOL. WT.

21.7370
13376
- 569.44
341935
1.27485
2.22593
527.40
1152.25

21.6686
14680
- 457.95
346077
1.27004
2.25645
557.13
1150.53

21.6524
15326
- 462.46
348117
1.26775
2.27091
651.99
1149.92

21.6822
14305
344951
1.27121
2.24737
577.00
1151.00

CO
CO2
H2
H2O
H2
O2
OH
H
NO
NH3
CH4

234963
3021488
310312
3056815
3042645

0236281
3020620
3102974
3057552
3042895

0237294
3019659
3102680
3058207
3042936

0237910
3019434
3102465
3058619
3042961

0236743
3020297
3102868
3057837
3042917

3000005
3000068
3000010
3000110

3000220
3000197
3000202
3000131

3000241
3000320

3000266
3000524

3000232
3000259

9.2

73

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.2

MIAI

TEMP. °K	2300.00	2400.00	2257.85
MOL. WT.	21.8747	21.8024	21.9196
P	33758	35324	33148
e	- 502.79	- 465.67	
CV	.250096	.351961	.349418
γ	1.26928	1.26691	1.26559
S	2.17609	2.19186	2.16969
E	590.00	626.49	574.47
HF	1148.12	1147.53	1148.47
CO	.0237256	.0238564	.0236423
CO2	.0017808	.0017273	.0018157
H2	.0096586	.0097686	.0096563
H2O	.0060823	.0061134	.0060617
N2	.0042559	.0042650	.0042506
O2			
OH	.0000004	.0000007	.0000003
H	.0000044	.0000072	.0000036
N			
NH3	.0000568	.0000527	.0000586
CH4	.0001100	.0000751	.0001321

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M1A1

G.3

TEMP. °K	1700.00	1800.00	1900.00	2000.00	2100.00	2200.00	2300.00
MOL. WT.	26.4458	25.1875	24.2183	23.5031	22.9793	22.6096	22.3255
P	39162	42570	45914	49140	52252	55239	58113
e	- 623.75	- 759.52	- 701.03	- 648.26	- 599.72	- 554.79	- 512.35
CV	.350522	.350664	.350758	.351570	.352961	.354036	.355246
γ	1.27016	1.27169	1.27264	1.27252	1.27122	1.26964	1.26856
S	1.96139	1.99810	2.02967	2.05673	2.08038	2.10125	2.12014
E	276.45	338.83	395.29	446.25	493.19	536.80	578.09
HF	1152.82	1151.65	1150.20	1148.82	1147.55	1146.46	1145.43
CO	.0180604	.0195927	.0208357	.0217857	.0225073	.0230345	.0234469
CO2	.0032781	.0027539	.0023568	.0020736	.0018654	.0017134	.0015934
H2	.0048390	.0057873	.0066534	.0073842	.0079671	.0083995	.0087366
H2O	.0057327	.0059976	.0061649	.0062601	.0063197	.0063617	.0063951
H2	.0033491	.0039404	.0040164	.0040768	.0041237	.0041590	.0041873
O							
OH							
H							
NO							
N							
NH3	.0000949	.0001044	.0001107	.0001128	.0001126	.0001101	.0001065
CH4	.0019591	.0015258	.0011529	.0008537	.0006204	.0004488	.0003145

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M1A1

0.3

TEMP. °K.	2400.00	2284.01
MOL. WT.	22.1469	22.3683
P	60882	57660
C	- 472.17	
CV	.356771	.355044
Z	1.26658	1.26870
S	2.13661	2.11724
E	617.51	571.63
HF	1144.63	1145.63
CO	.0237111	.0233879
CO2	.0015203	.0016106
H2	.0089683	.0086900
H2O	.0064119	.0063903
N2	.0042072	.0041832
O2		
OH	.0000005	.0000003
H	.0000052	.0000030
HO		
N		
H+3	.0001014	.0001071
CH4	.0002271	.0003337

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M1A1

0.4

TEMP. °K	2000.00	2100.00	2200.00	2300.00	2400.00	2316.90
MOL. WT.	24.6501	23.9830	23.4773	23.0482	22.7427	22.9887
P	73834	78666	83374	87968	92401	98728
e	- 673.62	- 621.75	- 573.18	- 526.91	- 483.35	
CV	.358356	.359719	.360416	.361411	.362601	.361599
γ	1.27170	1.27039	1.26917	1.26859	1.26707	1.26639
S	2.00291	2.02618	2.05074	2.07133	2.08925	2.07453
E	418.07	468.55	515.68	561.00	603.74	568.37
HF	1145.31	1144.32	1143.40	1142.50	1141.87	1142.37
CO	.208012	.0216472	.0223153	.0228872	.0232908	.0229604
CO2	.0020304	.0017815	.0015954	.0014440	.0013472	.0014240
H2	.0057490	.0063961	.0069429	.0074374	.0078173	.0075091
H2O	.0065732	.0066558	.0067040	.0067339	.0067412	.0067366
O2	.0039579	.0040097	.0040523	.0040899	.0041190	.0040953
OH						
H	.0000004	.0000001	.0000001	.0000003	.0000005	.0000003
NO		.0000007	.0000013	.0000023	.0000039	.0000026
NH3						
CH4	.0001561	.0001631	.0001664	.0001679	.0001654	.0001678
	.0012996	.0010333	.0008159	.0006246	.0004848	.0005976

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M2

0.05

TEMP. °K	1900.00	2000.00	2100.00	2200.00	2300.00	2400.00	2500.00
MOL. WT.	25.2475	25.2450	25.2430	25.2405	25.2380	25.2339	25.2277
P	4601	5057	5313	5568	5823	6079	6334
C	-1030.71	-946.49	-962.12	-927.59	-892.92	-858.07	-822.67
CV	331264	333977	336530	338816	340851	342900	344647
γ	1.24575	1.24299	1.24042	1.23812	1.23625	1.23453	1.23268
g	2.10092	2.11648	2.13525	2.15132	2.16674	2.18118	2.19603
g	452.57	485.34	510.44	551.85	585.43	619.45	653.55
HF	1541.89	1540.45	1539.18	1538.05	1536.96	1536.14	1534.85
CO	.0139957	.0141438	.0142710	.0143816	.0144731	.0145403	.0146393
CO2	.0004979	.0003513	.0002250	.0001156	.0000201	.0000597	.0000632
H2	.004731	.0043285	.0042053	.0040943	.0039986	.0039377	.0038410
H2O	.0097504	.0098093	.0099756	.0100891	.0101842	.0102439	.0103387
O2	.0049289	.0049295	.0049300	.0049304	.0049307	.0049312	.0049313
OH	.0000001	.0000002	.0000005	.0000011	.0000022	.0000041	.0000074
H	.0000006	.0000012	.0000021	.0000037	.0000062	.0000099	.0000151
NO	.0000003	.0000001	.0000001	.0000001	.0000001	.0000003	.0000006
N	.0000043	.0000036	.0000031	.0000027	.0000024	.0000022	.0000021
CH4	.0000009	.0000004	.0000002	.0000001	.0000001	.0000001	.0000001

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M2

0.05

TEMP. °K	2600.00	2700.00	2800.00	2900.00	3000.00	3100.00	3200.00
MCL. WT.	25.2153	25.2068	25.1892	25.1651	25.1316	25.0871	25.0283
P	5590	6847	7104	7363	7623	7885	8149
•	- 787.01	- 750.90	- 714.13	- 676.58	- 638.03	- 598.26	- 556.92
CV	346282	347762	349246	350557	351800	352918	353960
γ	1.23117	1.22989	1.22862	1.22750	1.22653	1.22573	1.22503
S	2.21002	2.22365	2.23702	2.25019	2.26320	2.27629	2.28941
E	689.03	722.70	757.65	793.28	829.11	865.35	902.10
HF	1533.67	1532.30	1530.61	1528.53	1525.84	1522.33	1517.75

CO	0.147072	0.147699	0.148284	0.148849	0.149424	0.150024	0.150689
CO2	0.057987	0.057411	0.056898	0.056431	0.055993	0.055575	0.055151
H2	0.037759	0.037183	0.036680	0.036239	0.035864	0.035552	0.035304
H2O	0.104500	0.104523	0.104551	0.104587	0.104632	0.104670	0.104700
H2	0.049323	0.049331	0.049340	0.049349	0.049363	0.049377	0.049393
O2	0.000001	0.000001	0.000003	0.000006	0.000013	0.000025	0.000045
OH	0.000001	0.000001	0.000003	0.000006	0.000012	0.000023	0.000042
H	0.000126	0.000207	0.000328	0.000502	0.000747	0.001081	0.001526
N2	0.000224	0.000323	0.000453	0.000622	0.000836	0.001102	0.001430
N	0.000012	0.000021	0.000037	0.000062	0.000099	0.000154	0.000233
•	0.000001	0.000002	0.000003	0.000005	0.000009	0.000014	0.000021
H3	0.000018	0.000017	0.000015	0.000017	0.000014	0.000014	0.000012
CH4							

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.05

M2

TEMP. °K	3300.00	3400.00	3500.00	3330.26
MOL. WT.	24.9519	24.8541	24.7304	24.9247
P	8417	8089	8937	8498
Q	- 513.68	- 468.15	- 419.87	
CV	.354875	.355703	.356455	.355130
γ	1.22451	1.22417	1.22404	1.22439
ρ	2.30271	2.31650	2.33029	2.30679
E	939.39	977.27	1015.83	950.78
HF	1511.89	1504.31	1494.67	1509.78

CO	.0151449	.0152345	.0153423	.0151705
CO2	.0054756	.0054215	.0053652	.0054563
H2	.0035130	.0035037	.0035043	.0035093
H2O	.0105605	.0105370	.0104978	.0105549
N2	.0049409	.0049426	.0049443	.0049414
O2	.0000000	.0000135	.0000219	.0000094
U	.0000074	.0000125	.0000203	.0000087
OH	.0002166	.0002644	.0003766	.0002311
H	.0001627	.0002304	.0002871	.0001962
NO	.0000342	.0000489	.0000683	.0000382
N	.0000032	.0000047	.0000067	.0000036
HO2	.0000012	.0000012	.0000011	.0000012
CH4				

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M2 0.1

TEMP. °K	1900.00	2000.00	2100.00	2200.00	2300.00	2400.00	2500.00
MOL. WT.	25.2620	25.2546	25.2503	25.2471	25.2440	25.2404	25.2352
P	11208	10756	11304	11651	12390	12943	13487
e	-1032.77	-998.59	-963.90	-929.25	-894.57	-859.72	-824.26
CV	1332062	1335375	1337977	1340240	1342189	1344265	1345999
J	1.25567	1.24731	1.24409	1.24122	1.23905	1.23668	1.23463
U	4.04054	2.58219	2.07502	2.09114	2.10657	2.12101	2.13585
L	446.98	432.02	915.33	548.00	582.59	613.72	650.92
MF	1540.36	1539.02	1537.83	1536.77	1535.78	1535.06	1533.90

CO	0.014217	0.0142700	0.0143953	0.0145032	0.0145979	0.0146583	0.0147550
CO2	0.003629	0.004197	0.006970	0.005909	0.005977	0.0058368	0.0057444
H2	0.0043217	0.0041805	0.0040677	0.0039639	0.0038719	0.0038137	0.0037202
H2O	0.0038339	0.0039834	0.010163	0.0102130	0.0103057	0.0103641	0.0104576
H	0.0049249	0.0049264	0.0049274	0.0049281	0.0049287	0.0049293	0.0049301
O							
N	0.0000001	0.0000002	0.0000004	0.0000008	0.0000015	0.0000029	0.0000052
NO	0.0000004	0.0000003	0.0000013	0.0000025	0.0000042	0.0000067	0.0000103
NO2					0.0000001	0.0000002	0.0000004
OH	0.0000005	0.00000079	0.0000068	0.0000059	0.0000052	0.0000047	0.0000038
HF	0.0000040	0.0000020	0.0000010	0.0000006	0.0000003	0.0000002	0.0000001

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.1

0.1

TEMP. °K	2600.00	2700.00	2800.00	2900.00	3000.00	3100.00	3200.00
MOL. WT.	25.2294	25.2204	25.2081	25.1919	25.1692	25.1378	25.1074
P	14333	14579	15127	15675	16226	16779	17336
e	- 768.63	- 753.00	- 716.64	- 679.71	- 642.04	- 603.55	- 562.94
CV	347574	345995	350473	351806	352984	354086	355154
γ	1.23278	1.23126	1.22965	1.22820	1.22694	1.22587	1.22481
S	2.14979	2.16331	2.17654	2.18950	2.20226	2.21487	2.22744
E	685.45	720.18	755.45	790.59	826.28	862.26	898.65
HF	1532.91	1531.81	1530.53	1528.95	1527.00	1524.50	1521.51

CO	0148202	0148600	0149348	0149803	0150377	0150888	0151433
CO2	0056816	0056254	0055756	0055308	0054820	0054503	0054123
H2	0026569	0026013	0025525	0025091	0024724	0024417	0024146
H2O	0105182	0105707	0106146	0106502	0106788	0106982	0107093
N2	0049505	0049311	0049318	0049323	0049336	0049344	0049355
O2	0000001	0000001	0000001	0000003	0000006	0000012	0000021
OH	0000088	0000145	0000230	0000353	0000525	0000761	0001077
H	0000153	0000220	0000309	0000424	0000570	0000751	0000973
NO	0000008	0000015	0000026	0000043	0000069	0000108	0000163
N	0000001	0000001	0000002	0000004	0000006	0000010	0000015
NH3	0000039	0000036	0000034	0000037	0000030	0000030	0000027
CH4	0000001	0000001	0000001	0000001	0000001	0000001	0000001

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.1

M2

TEMP. °K	3300.00	3400.00	3500.00	3354.16
MOL. WT.	25.0453	24.9788	24.8949	25.0111
P	17898	18464	19029	18204
e	- 523.02	- 480.55	- 436.23	
CV	.356098	.356931	.357763	.356557
γ	1.22397	1.22328	1.22277	1.22357
S	2.24002	2.25270	2.26554	2.24688
E	935.46	972.70	1010.40	955.57
HF	1517.23	1512.04	1505.49	1514.57
CO	.0152028	.0152704	.0153491	.0152384
CO2	.0053742	.0053340	.0052900	.0053527
H2	.0032941	.0033797	.0033723	.0033855
H2O	.0107107	.0107017	.0106810	.0107071
N2	.0049265	.0049374	.0049381	.0049370
O2	.0000035	.0000064	.0000105	.0000051
O	.0000036	.0000061	.0000099	.0000048
OH	.0001488	.0002015	.0002677	.0001759
H	.0001243	.0001565	.0001947	.0001411
NO	.0000240	.0000345	.0000425	.0000293
N	.0000022	.0000053	.0000047	.0000028
NH3	.0000026	.0000025	.0000024	.0000026
CH4				

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M2

0.2

TEMP. °K	2200.00	2300.00	2400.00	2500.00	2600.00	2700.00	2800.00
MOL. WT.	25.2645	25.2581	25.2532	25.2469	25.2426	25.2356	25.2266
P	27080	28325	29574	30814	32056	33300	34544
e	931.75	896.93	861.90	826.40	790.79	755.04	718.61
CV	343251	345009	347149	348858	350310	351569	353068
γ	1.24536	1.24282	1.23978	1.23716	1.23483	1.23303	1.23092
S	2.02473	2.04024	2.05476	2.06967	2.08364	2.09714	2.11031
L	543.37	577.32	611.75	646.26	681.03	715.90	751.15
HF	1533.72	1532.85	1532.25	1531.27	1530.44	1529.57	1528.58
CO	.0147799	.0148723	.0149302	.0150231	.0150840	.0151399	.0151904
CO2	.0057047	.0056161	.0055608	.0054709	.0054120	.0053591	.0053123
H2	.0036592	.0035763	.0035243	.0034384	.0033797	.0033285	.0032835
H2O	.0104958	.0105846	.0106349	.0107297	.0107869	.0108374	.0108802
N2	.0049223	.0049237	.0049248	.0049264	.0049266	.0049274	.0049282
O2							.0000001
O							.0000001
OH	.0000005	.0000011	.0000020	.0000036	.0000061	.0000101	.0000160
H	.0000016	.0000027	.0000043	.0000067	.0000099	.0000142	.0000200
NO		.0000001	.0000001	.0000003	.0000006	.0000010	.0000018
N						.0000001	.0000002
NH3	.0000142	.0000125	.0000113	.0000092	.0000093	.0000085	.0000080
CH4	.0000030	.0000017	.0000011	.0000007	.0000005	.0000003	.0000002

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.2

M2

TEMP. °K	2900.00	3000.00	3100.00	3200.00	3300.00	3400.00	3500.00
MOL. WT.	25.2163	25.1987	25.1782	25.1504	25.1152	25.0705	25.0140
P	35788	37036	38296	39540	40800	42065	43329
e	- 682.10	- 644.95	- 607.21	- 568.65	- 529.17	- 488.64	- 446.92
CV	.354375	.355464	.356507	.357567	.358506	.359306	.360204
γ	1.22903	1.22738	1.22599	1.22453	1.22325	1.22220	1.22129
S	2.12317	2.12578	2.14814	2.16037	2.17251	2.18460	2.19668
E	786.60	822.40	858.34	894.67	931.32	968.26	1005.50
HF	1527.39	1526.00	1524.23	1522.00	1519.19	1515.54	1511.20

CO	.0152961	.0152826	.0152693	.0153718	.0154194	.0154717	.0155307
CO2	.0052709	.0052316	.0051963	.0051621	.0051289	.0050949	.0050592
H2	.0032424	.0032088	.0031767	.0031335	.0031325	.0031165	.0031056
H2O	.0105148	.0109454	.0109675	.0109230	.0109909	.0109911	.0109828
N2	.0049281	.0049297	.0049352	.0049312	.0049318	.0049322	.0049325
O2	.0000001	.0000003	.0000005	.0000009	.0000017	.0000028	.0000047
OH	.0000001	.0000003	.0000005	.0000009	.0000017	.0000028	.0000046
H	.0000240	.0000367	.0000535	.0000755	.0001040	.0001420	.0001891
HO	.0000274	.0000365	.0000485	.0000628	.0000802	.0001019	.0001254
NO	.0000030	.0000048	.0000075	.0000114	.0000165	.0000242	.0000340
N	.0000003	.0000004	.0000007	.0000011	.0000016	.0000023	.0000033
NH3	.0000081	.0000071	.0000070	.0000064	.0000061	.0000060	.0000056
CN4	.0000002	.0000001	.0000001	.0000001	.0000001	.0000001	.0000001

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M2

0.2

TEMP. °K 3371.58

MOL. WT. 25.0842
P 41705

e CV 359091
Y 1.22248
S 2.18117
E 957.73
HF 1516.73

CO 0.154564
CO2 0.0051047
H2 0.031207
H2O 0.0109919
N2 0.0049321
O2 0.0000024
O 0.0000024
OH 0.001305
H 0.0000947
NO 0.0000219
N 0.0000021
NH3 0.0000063
CH4 0.0000001

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.3

M2

TEMP. °K	2700.00	2800.00	2900.00	3000.00	3100.00	3200.00	3300.00
MOL. WT.	25.2456	25.2415	25.2342	25.2180	25.2019	25.1793	25.1513
P	57278	59397	61512	63635	65755	67831	70010
e	- 755.02	- 719.28	- 682.61	- 645.43	- 607.92	- 569.65	- 530.64
CV	.594344	.555869	.517149	.478139	.439113	.399196	.361081
γ	1.23562	1.23315	1.23092	1.22902	1.22741	1.22565	1.22410
S	2.05298	2.06619	2.07905	2.09165	2.10393	2.11607	2.12805
E	712.37	747.89	783.56	819.62	855.69	892.18	928.93
HF	1526.61	1525.79	1524.79	1523.69	1522.26	1520.49	1518.25

CO	.0154596	.0154866	.0155273	.0155711	.0156100	.0156507	.0156923
CO2	.0050521	.0050097	.0049721	.0049349	.0049027	.0048713	.0048412
H2O	.0030118	.0029713	.0029330	.0029042	.0028767	.0028541	.0028351
H2	.0111417	.0111820	.0112157	.0112444	.0112656	.0112823	.0112919
N2	.0049228	.0049257	.0049232	.0049255	.0049259	.0049270	.0049276
O2			.0000001	.0000002	.0000003	.0000005	.0000010
O			.0000001	.0000002	.0000003	.0000006	.0000010
CH	.0000031	.0000129	.0000199	.0000297	.0000432	.0000612	.0000849
H	.0000104	.0000145	.0000199	.0000268	.0000353	.0000458	.0000584
HC	.0000008	.0000015	.0000024	.0000039	.0000061	.0000093	.0000137
N	.0000001	.0000001	.0000002	.0000003	.0000006	.0000009	.0000013
NH3	.0000153	.0000143	.0000158	.0000126	.0000125	.0000113	.0000108
CH4	.0000009	.0000007	.0000005	.0000004	.0000003	.0000002	.0000002

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M2 0.3

TEMP. °K 3400.00 3500.00 3376.39

MOL. WT.
P 25.1162 25.0716 25.1251
e 72142 74286 71639
CV - 490.83 - 450.12
γ .361813 .362752 .361655
S 1.22281 1.22164 1.22309
E 2.13993 2.15172 2.13714
HF 965.90 1002.05 957.15
1515.43 1511.91 1516.15

CO	.0157372	.0157872	.0157263
CO2	.0046107	.0047789	.0048179
H2	.0028195	.0028067	.0028229
H2O	.0112950	.0112912	.0112949
N2	.0049279	.0049281	.0049273
O2	.0000017	.0000028	.0000015
O	.0000017	.0000029	.0000015
OH	.0001155	.0001540	.0001076
H	.0000735	.0000914	.0000697
NO	.0000197	.0000278	.0000182
N	.0000019	.0000027	.0000017
NH3	.0000105	.0000099	.0000106
CH4	.0000001	.0000001	.0000002

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.4

M2

TEMP. °K	2900.00	3000.00	3100.00	3200.00	3300.00	3400.00	3500.00
MOL. WT.	25.2526	25.2557	25.2220	25.2019	25.1780	25.1484	25.1106
P	53884	97085	100275	103470	106665	109857	113060
e	- 681.76	- 644.45	- 606.96	- 568.74	- 529.88	- 490.36	- 450.16
CV	360126	361012	361914	362996	363840	364493	365465
γ	1.23467	1.23256	1.23076	1.22876	1.22699	1.22551	1.22414
S	2.04357	2.03620	2.02847	2.02059	2.01253	2.10431	2.11595
E	781.28	817.69	853.95	890.69	927.64	964.76	1001.98
HF	1521.65	1520.76	1519.55	1518.07	1516.19	1513.81	1510.85

CO	.0158462	.0158884	.0159233	.0159605	.0159977	.0160375	.0160819
CO2	.0046452	.0046100	.0045809	.0045520	.0045247	.0044970	.0044681
H2	.0025926	.0025683	.0025442	.0025249	.0025085	.0024948	.0024854
H2O	.0115385	.0115688	.0115883	.0116046	.0116143	.0116181	.0116163
N2	.0049170	.0049204	.0049208	.0049222	.0049229	.0049231	.0049234
O2	.0000001	.0000001	.0000002	.0000004	.0000007	.0000011	.0000019
O	.0000001	.0000001	.0000002	.0000004	.0000007	.0000012	.0000020
OH	.0000171	.0000255	.0000371	.0000528	.0000735	.0000998	.0001333
H	.0001150	.0001202	.0001267	.0001346	.0001441	.0001556	.0001691
NO	.0000021	.0000034	.0000053	.0000081	.0000120	.0000173	.0000244
N	.0000003	.0000003	.0000005	.0000007	.0000011	.0000016	.0000023
NH3	.0000249	.0000199	.0000197	.0000178	.0000169	.0000165	.0000156
CH4	.0000011	.0000008	.0000006	.0000005	.0000004	.0000003	.0000003

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

H2 0.4

TEMP. °K 3374.96

MOL. WT.
P 25.1564
C 109059

CV 364348
γ 1.22585
S 2.10138
E 955.45
HF 1514.45

CO .0160273
CO2 .0045040
H2 .0024980
H2O .0116177
N2 .0049231
O2 .0000010
O .0000001
OH .0000926
H .0000525
NO .0000159
N .0000015
NH3 .0000156
CH4 .0000003

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M5

0.05

TEMP. °K	1800.00	1900.00	2000.00	2100.00	2200.00	2300.00	2400.00
MOL. WT.	25.0000	25.0154	25.0125	25.0104	25.0081	25.0052	25.0008
P	4589	4848	5106	5364	5622	5880	6138
e	-1042.63	-1008.41	-974.17	-939.79	-905.24	-870.56	-835.72
CV	328374	333929	33929	336472	338750	340780	342825
Y	1.25100	1.24767	1.24511	1.24252	1.24021	1.23834	1.23642
S	2.09214	2.11064	2.12821	2.14499	2.16106	2.17648	2.19090
E	420.37	452.91	485.69	518.77	552.15	585.74	619.77
HF	1521.35	1519.67	1518.21	1516.92	1515.75	1514.66	1513.86
CO	.0144879	.0146378	.0147885	.0149179	.0150301	.0151286	.0151921
CO2	.0063910	.0062149	.0060658	.0059376	.0058264	.0057292	.0056678
H2O	.0049493	.0047766	.0046323	.0045053	.0043946	.0042974	.0042355
H2	.0053127	.0094691	.0096382	.0097666	.0098777	.0099746	.0100356
O2	.0048475	.0048485	.0048491	.0048496	.0048500	.0048504	.0048510
OH							
H	.0000001	.0000001	.0000002	.0000005	.0000010	.0000021	.0000039
N2	.0000006	.0000006	.0000012	.0000022	.0000039	.0000064	.0000102
N							
NO	.0000001	.0000001	.0000001	.0000001	.0000001	.0000001	.0000003
NO2							
HT3	.0000058	.0000048	.0000040	.0000034	.0000030	.0000027	.0000024
CH4	.0000026	.0000012	.0000006	.0000003	.0000002	.0000001	.0000001

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.05

M5

TEMP. °K	2500.00	2600.00	2700.00	2800.00	2900.00	3000.00	3100.00
MOL. WT.	24.9950	24.9868	24.9747	24.9576	24.9345	24.9023	24.8599
P	6396	6654	6913	7173	7433	7695	7960
e	- 600.33	- 764.08	- 728.59	- 691.87	- 654.39	- 615.95	- 576.33
CV	344266	346198	347696	349159	350501	351717	352839
γ	1.23477	1.23325	1.23196	1.23068	1.22955	1.22857	1.22776
z	2.20570	2.2.973	2.23337	2.24672	2.25987	2.27290	2.28588
z	603.63	668.29	723.00	758.06	793.45	829.23	865.40
HF	1512.52	1511.34	1509.97	1508.32	1506.24	1503.60	1500.19
CO	.0152926	.0153016	.0154251	.0154842	.0155409	.0155983	.0156574
CO2	.0055656	.0055640	.0054456	.0053936	.0053465	.0053027	.0052614
H2	.041309	.040704	.040116	.039621	.039146	.038759	.038432
H2O	.101321	.101947	.102482	.102923	.103271	.103531	.103683
N2	.0048515	.0048521	.0048528	.0048538	.0048547	.0048562	.0048576
N2			.000001	.000003	.000005	.000011	.000020
O		.0000001	.0000001	.0000003	.0000006	.000011	.000021
OH	.0000009	.0001119	.0001195	.0001309	.0001474	.0001704	.0001920
H	.0000137	.0000232	.0000335	.0000471	.0000646	.0000869	.0001146
H2O	.0000000	.0000011	.0000019	.0000033	.0000056	.0000089	.0000139
N		.0000001	.0000002	.0000003	.0000005	.0000009	.0000014
CH4	.0000000	.0000000	.0000000	.0000001	.0000001	.0000001	.0000001

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.05

M5

TEMP. °K	3200.00	3300.00	3400.00	3260.58
MOL. WT.	24.8039	24.7516	24.6395	24.7622
P	8226	6496	8770	9389
e	- 555.23	- 452.33	- 447.20	
CV	253885	354814	355657	354465
7	1.22704	1.22650	1.22613	1.22609
S	2.29592	2.31213	2.32555	2.30690
E	902.06	939.23	976.96	924.51
HF	1495.79	1490.11	1462.84	1492.51
CO	.0157322	.0157953	.0158809	.0157654
CO2	.0052202	.0051777	.0051316	.0051846
H2O	.0038188	.0037974	.0037658	.0038041
H2	.0107701	.0103625	.0103443	.0103700
H2	.0046593	.0046610	.0048627	.0048603
O2	.0000037	.0000066	.000011	.0000053
OH	.0000038	.0000067	.000013	.0000054
H	.0001440	.0001988	.0002686	.0001751
NO	.0001486	.0001899	.0002394	.0001727
NO	.0002210	.0003038	.0003441	.0002266
N2	.0000021	.0000032	.0000046	.0000027
CH4	.0000014	.0000013	.0000013	.0000013

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.1

M5

TEMP. °K	1800.00	1900.00	2000.00	2100.00	2200.00	2300.00	2400.00
MOL. WT.							
P	28.0516	25.0328	25.0238	25.0187	25.0151	25.0118	25.0081
e	9752	10311	10865	11418	11970	12520	13072
CV	-1045.10	-1010.40	-976.03	-941.51	-906.85	-872.16	-837.31
Y	.329929	.332657	.335334	.337923	.340184	.342122	.344193
S	1.23045	1.25260	1.24930	1.24608	1.24321	1.24103	1.23866
E	2.33336	2.04766	2.06735	2.08419	2.10031	2.11575	2.13018
HF	4.0.20	449.28	462.36	515.67	549.24	582.92	617.04
	1519.02	1516.58	1516.73	1515.53	1514.44	1513.44	1512.71
CO	.014573	.0177643	.0149165	.0150447	.0151548	.0152514	.0153129
CO2	.0022540	.0030773	.0059311	.0058062	.0056982	.0056033	.0055435
HE	.0047760	.0046238	.0044830	.0043652	.0042599	.0041665	.0041073
H2O	.0044490	.0056255	.0097715	.0098965	.0100047	.0100995	.0101590
H2	.0042410	.0042440	.0048437	.0048468	.0048476	.0048483	.0048488
OH							
CH	.0000002	.0000001	.0000001	.0000003	.0000007	.0000014	.0000027
T		.0000004	.0000008	.0000015	.0000026	.0000044	.0000070
NO						.0000001	.0000002
NH3	.0000126	.0000104	.0000067	.0000075	.0000066	.0000058	.0000052
CH4	.0000116	.0000052	.0000026	.0000014	.0000008	.0000005	.0000003

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M5

O.1

TEMP. °K	2500.00	2600.00	2700.00	2800.00	2900.00	3000.00	3100.00
MOL. WT.	25.0000	24.9971	24.9884	24.9764	24.9608	24.9379	24.9089
P	13021	14172	14723	15276	15829	16385	16943
Q	- 801.95	- 750.43	- 730.51	- 694.28	- 657.41	- 619.81	- 581.42
Y	1.23062	1.23476	1.23324	1.23162	1.23017	1.22890	1.22783
Z	2.14003	2.15897	2.17248	2.18570	2.19864	2.21138	2.22395
HF	651.23	635.75	720.46	755.50	790.81	826.47	862.39
	1511.54	1510.54	1509.44	1508.16	1506.60	1504.93	1502.25

CO	1.154-14	1.154772	1.155386	1.155942	1.156460	1.156973	1.157484
CO2	1.054-73	1.053854	1.053263	1.052757	1.052234	1.051684	1.051148
H2O	1.043-22	1.043547	1.043893	1.044190	1.044437	1.044616	1.044759
H2	1.032-45	1.032161	1.032068	1.031915	1.031719	1.031483	1.031201
N2	1.043-97	1.043351	1.043001	1.042631	1.042252	1.041863	1.041462
O2	1.031-47	1.031083	1.030817	1.030541	1.030265	1.029989	1.029713
H	1.001-07	1.001159	1.001229	1.001301	1.001371	1.001439	1.001506
NO	1.000-04	1.000007	1.000013	1.000019	1.000025	1.000031	1.000037
NO2	1.000-43	1.000001	1.000001	1.000001	1.000001	1.000001	1.000001
OH	1.000-02	1.000001	1.000001	1.000001	1.000001	1.000001	1.000001

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.1

M5

TEMP. °K	3200.00	3300.00	3400.00	3280.01
MOL. WT.	24.8704	24.8209	24.7582	24.8317
P	17505	18070	18641	17957
e	- 541.98	- 501.28	- 459.11	
CV	.355080	.256021	.356875	.355844
γ	1.22678	1.22590	1.22519	1.22606
S	2.23647	2.24899	2.26157	2.24649
E	898.72	935.44	972.58	928.07
HF	1499.15	1495.21	1490.22	1496.07

CO	.0158020	.0158599	.0159248	.0158479
CO2	.0051124	.0050753	.0050369	.0050827
H2	.0036985	.0036766	.0036605	.0035825
H2O	.0105146	.0105175	.0105101	.0105177
N2	.0048554	.0048565	.0048574	.0048563
O2	.0000017	.0000031	.0000052	.0000028
O	.0000019	.0000032	.0000055	.0000029
OH	.0001015	.0001404	.0001901	.0001318
H	.0001013	.0001294	.0001629	.0001233
NO	.0000147	.0000216	.0000310	.0000201
N	.0000015	.0000022	.0000033	.0000021
NH3	.0000030	.0000029	.0000028	.0000029
CH4				

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

C.2

M5

TEMP. °K	2200.00	2300.00	2400.00	2500.00	2600.00	2700.00	2800.00
MOL. WT.	25.0355	25.0220	25.0225	25.0156	25.0113	25.0042	24.9954
P	27362	28619	29880	31131	32395	33640	34879
e	- 909.25	- 874.40	- 839.36	- 803.85	- 768.24	- 732.51	- 696.29
CV	343202	344954	347086	348788	350237	351495	352991
γ	1.24718	1.24464	1.24162	1.23901	1.23668	1.23482	1.23277
S	2.03329	2.04280	2.05332	2.07324	2.09220	2.10571	2.11838
E	543.70	577.67	612.10	646.51	681.37	716.33	751.46
HF	1511.28	1510.41	1509.81	1508.81	1507.57	1506.10	1506.12

CO	0154370	0155324	0155221	0156872	0157494	0158064	0158579
CO2	0054043	0053137	0052572	0051654	0051033	0050314	0049538
H2	0039453	0038599	0038075	0037204	0036607	0036015	0035423
H2O	0102957	0103654	0104429	0105346	0106330	010748	0108687
N2	0048410	0048426	0048438	0048456	0048459	0048465	0048474
O2	0000005	0000010	0000019	0000034	0000058	0000095	0000151
OH	0000017	0000028	0000045	0000069	0000103	0000149	0000203
H	00000158	00000140	00000126	00000103	0000084	0000096	0000095
H3	0000040	0000023	0000015	0000010	0000006	0000005	0000003
CH4							

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M5

0.2

TEMP. °K	2900.00	3000.00	3100.00	3200.00	3300.00	3400.00	3293.74
MOL. WT.	24.9856	24.9684	24.9487	24.9221	24.8886	24.8464	24.8909
e	36150	37409	38670	39935	41205	42480	41125
CV	- 659.68	- 622.52	- 584.86	- 546.40	- 507.07	- 466.76	- 358285
γ	1.23067	1.22923	1.22753	1.22637	1.22509	1.22402	1.22517
S	2.13172	2.14421	2.15664	2.16884	2.18094	2.19296	2.18018
E	786.88	822.66	858.57	894.85	931.44	968.31	929.14
HF	1504.93	1503.57	1501.83	1499.67	1496.95	1493.54	1497.14

CO	.0159041	.0159511	.0159947	.0160399	.0160866	.0161373	.0160836
CO2	.0049618	.0049221	.0048867	.0048527	.0048200	.0047872	.0048220
H2	.0035204	.0034861	.0034550	.0034290	.0034073	.0033898	.0034085
H2O	.0107243	.0107561	.0107790	.0107958	.0108049	.0108064	.0108046
H2	.0048473	.0048491	.0048497	.0048507	.0048515	.0048520	.0048514
O2	.0000001	.0000002	.0000004	.0000008	.0000013	.0000023	.0000013
O	.0000001	.0000002	.0000005	.0000009	.0000015	.0000025	.0000015
OH	.0000232	.0000346	.0000502	.0000712	.0000986	.0001338	.0000967
H	.0000265	.0000383	.0000505	.0000655	.0000836	.0001052	.0000824
H2O	.0000027	.0000043	.0000067	.0000102	.0000151	.0000217	.0000147
N	.0000003	.0000004	.0000007	.0000010	.0000016	.0000023	.0000015
NH3	.0000100	.0000080	.0000079	.0000072	.0000069	.0000067	.0000069
CH4	.0000002	.0000002	.0000001	.0000001	.0000001	.0000001	.0000001

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.3

M5

TEMP. °K	2500.00	2600.00	2700.00	2800.00	2900.00	3000.00	3100.00
MOL. WT.	25.0321	25.0273	25.0196	25.0116	25.0048	24.9885	24.9730
C	53588	55726	57866	60004	62136	64273	66416
H	- 804.56	- 768.75	- 732.93	- 696.60	- 659.96	- 622.82	- 585.37
CV	.351863	.353187	.354277	.355798	.357076	.358066	.359042
Y	1.24201	1.23936	1.23740	1.23492	1.23270	1.23090	1.22919
S	2.03357	2.04763	2.06115	2.07436	2.08722	2.09980	2.11206
E	642.57	677.65	712.73	748.24	783.38	819.94	855.97
HF	1505.47	1504.74	1504.01	1503.20	1502.20	1501.13	1499.73
CO	.0160026	.0160614	.0161155	.0161636	.0162049	.0162496	.0162886
CO2	.0048415	.0047855	.0047350	.0046907	.0046525	.0046148	.0045824
H2	.0033795	.0033258	.0032793	.0032381	.0031993	.0031657	.0031414
H2O	.0168951	.0169103	.0169592	.0170036	.0170432	.0170791	.01711873
H2	.0048398	.0048400	.0048414	.0048424	.0048417	.0048444	.0048449
O2					.0000001	.0000001	.0000002
OH	.0000027	.0000046	.0000077	.0000122	.0000201	.0000302	.0000403
H	.0000000	.0000075	.0000108	.0000152	.0000208	.0000280	.0000369
NO	.0000002	.0000004	.0000007	.0000013	.0000022	.0000035	.0000055
N			.0000001	.0000001	.0000002	.0000003	.0000006
NO2	.0000186	.0000189	.0000173	.0000162	.0000179	.0000143	.0000142
CH4	.0000027	.0000018	.0000013	.0000010	.0000007	.0000005	.0000004

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

MS 0.3

TEMP. °K	3200.00	3300.00	3400.00	3296.75
MOL. WT.	24.9512	24.9246	24.8914	24.9255
P	68560	70707	72855	70637
e	- 547.19	- 508.31	- 468.67	
CV	360126	361014	361753	360988
γ	1.22743	1.22587	1.22458	1.22592
S	2.12417	2.13612	2.14794	2.13573
E	892.43	929.13	966.03	927.93
HF	1498.01	1495.85	1493.14	1495.93
CO	.0163292	.0163701	.0164137	.0163688
CO2	.0045510	.0045213	.0044916	.0045222
H2	.0031182	.0030985	.0030820	.0030990
H2O	.0111050	.0111156	.0111198	.0111154
H2	.0048461	.0048468	.0048472	.0048468
O2	.0000004	.0000008	.0000014	.0000008
O	.0000005	.0000009	.0000016	.0000009
OH	.0000576	.0000800	.0001087	.0000792
H	.0000479	.0000611	.0000769	.0000606
NO	.0000083	.0000122	.0000176	.0000121
N	.0000008	.0000017	.0000019	.0000013
NH3	.0000129	.0000123	.0000120	.0000123
CH4	.0000003	.0000003	.0000002	.0000003

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M5

0.4

TEMP. °K	2800.00	2900.00	3000.00	3100.00	3200.00	3300.00	3400.00
MOL. WT.	25.0301	25.0253	25.0078	24.9945	24.9749	24.9520	24.9241
P	510.95	94816	96045	101260	104481	107701	110917
e	- 633.72	- 636.94	- 621.60	- 564.23	- 546.03	- 507.34	- 467.98
CV	358805	355057	360941	361843	362525	363770	364429
γ	1.23889	1.23639	1.23430	1.23251	1.23090	1.22872	1.22725
z	2.03852	2.05143	2.06409	2.07631	2.08840	2.10030	2.11204
z	745.71	751.62	816.02	854.27	890.97	927.65	964.95
H	1499.77	1493.95	1458.04	1496.86	1495.44	1493.63	1491.34
CO	0104980	0165340	0165721	0166132	0166506	0166873	0167260
CO2	0043474	0043133	0042776	0042463	0042192	0041923	0041654
H2	0027751	0028433	0028192	0027945	0027749	0027580	0027437
H2O	0113412	0113596	0114014	0114217	0114391	0114497	0114545
O2	0048235	0048346	0048285	0048389	0048406	0048414	0048417
N2	0000001	0000001	0000001	0000002	0000003	0000005	0000009
N	0000001	0000001	0000001	0000002	0000004	0000006	0000011
H	0000004	0000006	0000009	0000012	0000016	0000020	0000025
Ar	0000001	0000001	0000001	0000001	0000001	0000001	0000001
CH4	0000001	0000001	0000001	0000001	0000001	0000001	0000001

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.4

M5

TEMP. °K 3294.20

MOL. WT.
P 24.9535
• 107514
CV 363728
T 22882
S 203961
E 925.74
HF 1493.74

CO 0.166852
CO2 0.041938
H2 0.027589
H2O 0.114493
• 0.048414
• 0.010005
• 0.000006
• 0.000677
• 0.000457
• 0.000104
• 0.000011
• 0.000195
• 0.000006

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M6

0.05

TEMP. °K	1400.00	1500.00	1600.00	1700.00	1800.00	1900.00	2000.00
MOL. WT.	24.8862	23.5691	22.9875	22.7549	22.6624	22.6230	22.6047
P	3774	4162	4500	4810	5106	5397	5686
C	- 943.12	- 877.03	- 820.51	- 788.86	- 752.78	- 717.93	- 683.55
CV	.319027	.319685	.321737	.324436	.327277	.329958	.332539
γ	1.27542	1.28047	1.28066	1.27849	1.27557	1.27264	1.26987
S	2.06964	2.11553	2.14669	2.17074	2.19137	2.21020	2.22783
E	241.47	303.04	350.86	388.30	422.60	455.92	489.03
HF	1238.43	1236.65	1234.32	1232.25	1230.51	1229.03	1227.76

CO	.1175074	.0194123	.0203940	.0209035	.0211996	.0214004	.0215503
CO2	.0043455	.0042789	.0038625	.0035870	.0033849	.0032235	.0030915
H2	.0072606	.0064016	.0038450	.0089319	.0088743	.0087749	.0086709
H2O	.0030435	.0054176	.0056266	.0059013	.0060799	.0062314	.0063593
NO	.0043258	.0044460	.0045036	.0045232	.0045387	.0045437	.0045464
NO2							
H							
OH			.0000001	.0000002	.0000004	.0000008	.0000001
O							.0000016

CO	.0002238	.0002225	.0000194	.0000163	.0000137	.0000116	.0000100
CO2	.0000901	.0000493	.0001866	.0000777	.0000344	.0000163	.0000084

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M6

0.05

TEMP. °K	2100.00	2200.00	2300.00	2400.00	2500.00	2600.00	2700.00
MOL. WT.	22.5950	22.5889	22.5838	22.5787	22.5721	22.5650	22.5548
P	5574	5261	6547	6833	7119	7406	7693
Q	- 645.21	- 614.79	- 580.27	- 545.59	- 510.42	- 475.02	- 439.22
CV	.334966	.337214	.339222	.341239	.342965	.344602	.346123
T	1.26724	1.26484	1.26288	1.26090	1.25919	1.25759	1.25621
S	2.24458	2.24058	2.23593	2.23010	2.230506	2.231894	2.23246
E	522.23	555.03	589.17	625.08	657.05	691.35	725.88
HF	1226.63	1225.61	1224.64	1223.87	1222.69	1221.58	1220.32

CO	.0216712	.0217725	.0218598	.0219158	.0220033	.0220627	.0221173
CO2	.0029757	.0028837	.0028002	.0027476	.0026641	.0026088	.0025599
H2	.0095727	.0084836	.0084036	.0083521	.0082691	.0082110	.0081591
H2O	.0064692	.0065644	.0066473	.0066995	.0067825	.0068365	.0068835
N2	.0045475	.0045490	.0045499	.0045507	.0045518	.0045523	.0045534
O2							
OH	.0000002	.0000005	.0000010	.0000018	.0000033	.0000056	.0000092
H	.0000030	.0000053	.0000089	.0000143	.0000221	.0000330	.0000477
N				.0000001	.0000002	.0000003	.0000006
H3	.0000000	.0000079	.0000071	.0000065	.0000054	.0000041	.0000032
CH4	.0000047	.0000028	.0000017	.0000011	.0000007	.0000005	.0000004

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.05

46

TEMP. °K	2600.00	2572.09
MOL. WT.	22.5413	22.5666
P	7961	7343
e	- 402.90	
CV	.347593	.344251
Y	1.25485	1.25793
S	2.34566	2.31599
E	760.69	683.91
HF	1218.21	1221.81
CO	.0221674	.0220521
CO2	.0025172	.0026185
H2	.0081121	.0002216
H2O	.0069231	.0060272
H2	.0045546	.0045523
O2		
OH	.000001	
H	.0000145	.0000050
H2O	.0000673	.0000303
H2	.000011	.0000033
H2	.0000003	.0000001
H2	.0000000	.0000000
CH4	.0000003	.0000005

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105

10

1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053	2054	2055	2056	2057	2058	2059	2060	2061	2062	2063	2064	2065	2066	2067	2068	2069	2070	2071	2072	2073	2074	2075	2076	2077	2078	2079	2080	2081	2082	2083	2084	2085	2086	2087	2088	2089	2090	2091	2092	2093	2094	2095	2096	2097	2098	2099	2100
2100.00	2200.00	2300.00	2400.00	2500.00	2600.00	2700.00	2800.00	2900.00	3000.00	3100.00	3200.00	3300.00	3400.00	3500.00	3600.00	3700.00	3800.00	3900.00	4000.00	4100.00	4200.00	4300.00	4400.00	4500.00	4600.00	4700.00	4800.00	4900.00	5000.00	5100.00	5200.00	5300.00	5400.00	5500.00	5600.00	5700.00	5800.00	5900.00	6000.00	6100.00	6200.00	6300.00	6400.00	6500.00	6600.00	6700.00	6800.00	6900.00	7000.00	7100.00	7200.00	7300.00	7400.00	7500.00	7600.00	7700.00	7800.00	7900.00	8000.00	8100.00	8200.00	8300.00	8400.00	8500.00	8600.00	8700.00	8800.00	8900.00	9000.00	9100.00	9200.00	9300.00	9400.00	9500.00	9600.00	9700.00	9800.00	9900.00	10000.00																																																																																	

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.1

M6

TEMP. °K	2800.00	2581.14
MOL. WT.	22.5630	22.5853
P	17067	15725
e	- 404.50	
CV	348957	345737
Z	1.25441	1.25799
S	2.27802	2.24895
E	758.98	683.00
HF	1218.59	1221.00
CO	.0222663	.0221555
CO2	.0024054	.0025029
H2O	.0079930	.0080913
H2	.0070562	.0065428
O2	.0045495	.0045472
OH	.0000101	.0000039
H	.0000463	.0000211
O	.0000007	.0000002
N2	.0000002	.0000001
N	.0000112	.0000123
CH4	.0000013	.0000026

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M6

O.2

TEMP. °K	1700.00	1800.00	1900.00	2000.00	2100.00	2200.00	2300.00
MOL. WT.	24.6747	23.8508	23.3369	23.0395	22.8692	22.7722	22.7103
P	22705	24532	26187	27770	29288	30763	32201
Q	- 638.35	- 734.29	- 737.39	- 695.78	- 637.10	- 620.06	- 584.04
CV	334713	335540	336683	338447	340560	342461	344132
γ	1.27389	1.27615	1.27509	1.27292	1.26994	1.26694	1.26473
S	2.00363	2.03453	2.05986	2.08120	2.10006	2.11726	2.13220
E	333.96	386.44	431.82	472.21	509.85	546.01	581.24
HF	1225.22	1225.14	1223.94	1222.89	1221.97	1221.15	1220.40
CO	0.190005	0.0201874	0.0209666	0.0214549	0.0217673	0.0219727	0.0221235
CO2	0.0036732	0.0032590	0.0029664	0.0027681	0.0026240	0.0025146	0.0024246
H2	0.0062649	0.0069823	0.0074264	0.0076726	0.0077886	0.0078289	0.0078337
H2O	0.0062505	0.0064848	0.0066542	0.0067784	0.0068796	0.0069650	0.0070402
O2	0.0043243	0.0043994	0.0044497	0.0044810	0.0045001	0.0045120	0.0045201
O							
OH							
H	0.0000001	0.0000002	0.0000004	0.0000007	0.0000013	0.0000024	0.0000035
HO							
CH4	0.0000639	0.0000629	0.0000593	0.0000544	0.0000496	0.0000452	0.0000414
C2H4	0.0000880	0.0000513	0.0000275	0.0000136	0.0000160	0.0000122	0.0000088

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.2

M6

TEMP. °K	2400.00	2500.00	2600.00	2700.00	2800.00	2583.46
MOL. WT.	22.6745	22.6453	22.6309	22.6164	22.6039	22.5323
P	33626	35038	36441	37845	39245	36210
e	- 348.43	- 512.62	- 476.94	- 441.19	- 405.11	
CV	346088	347702	349155	350457	351933	348926
γ	1.26203	1.25966	1.25743	1.25560	1.25356	1.25779
g	2.17787	2.16309	2.17710	2.19059	2.20371	2.17486
z	616.30	651.27	686.18	721.16	756.38	680.41
H _f	1219.87	1219.05	1218.29	1217.53	1216.68	1218.41
CO	.0222125	.0223197	.0223856	.0224433	.0224920	.0223776
CO ₂	.0023659	.0022886	.0022365	.0021906	.0021511	.0022431
H ₂	.0076324	.0077928	.0077570	.0077254	.0076941	.0077627
H ₂ O	.0070570	.0071636	.0072115	.0072547	.0072917	.0072056
H ₂	.0045253	.0045314	.0045322	.0045347	.0045366	.0045324
O ₂						
O						
OH	.0000009	.0000016	.0000027	.0000044	.0000059	.0000025
H	.0000064	.0000100	.0000149	.0000216	.0000304	.0000140
NO		.0000001	.0000002	.0000003	.0000005	.0000001
N ₂				.0000001	.0000002	
N ₂				.0000001	.0000002	
N ₂				.0000001	.0000002	
CH ₄	.00000380	.00000317	.00000328	.00000306	.00000290	.00000321
	.00000299	.00000199	.00000139	.00000100	.00000076	.00000146

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.3

M6

TEMP. °K	2000.00	2100.00	2200.00	2300.00	2400.00	2500.00	2600.00
MOL. WT.	23.5957	23.3445	23.1025	22.9416	22.8450	22.7687	22.7300
g	47459	50252	52931	55508	58026	60499	62929
e	- 711.06	- 667.48	- 625.85	- 588.25	- 550.94	- 513.83	- 477.31
CV	343664	345408	346885	348206	350010	351453	352720
γ	1.77295	1.27032	1.26789	1.26608	1.26338	1.26094	1.25858
g	2.02421	2.04544	2.06431	2.08150	2.09680	2.11255	2.12690
E	453.23	495.65	535.65	573.51	611.35	646.76	682.60
H _F	1219.80	1318.05	1217.38	1216.74	1216.32	1215.68	1215.02
CO	.0210003	.0215379	.0219055	.0221724	.0223330	.0224906	.0225838
CO ₂	.0026065	.0024124	.0022715	.0021602	.0020938	.0020071	.0019536
H ₂	.0065478	.0066753	.0070792	.0072114	.0072918	.0073203	.0073227
H ₂ O	.0070352	.0071925	.0072766	.0073482	.0073916	.0074635	.0075055
CH ₄	.0043926	.0044348	.0044598	.0044783	.0044905	.0045038	.0045065
CH	.0000003	.0000001	.0000002	.0000004	.0000007	.0000012	.0000021
NO	.0000003	.0000010	.0000017	.0000029	.0000047	.0000074	.0000110
N ₂	.0000935	.0000396	.0000845	.00009791	.0000736	.0000622	.0000645
OH	.004693	.0005114	.0002062	.0001360	.0000935	.0000636	.0000449

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.3

M6

TEMP. °K	2700.00	2800.00	2584.61
MOL. WT.	22.6971	22.6735	22.7336
P	65352	67758	6255A
e	- 441.01	- 404.50	.352536
CV	.353656	.355253	1.25894
γ	1.25669	1.25440	2.12478
S	2.14060	2.15388	677.12
E	718.29	754.10	1215.12
HF	1214.42	1213.75	
CO	.0226599	.0227189	.0225736
CO2	.0019074	.0018690	.0019597
H2O	.0073217	.0073117	.0073240
H2	.0075448	.0075783	.0075009
O2	.0045117	.0045155	.0045067
OH			
H	.0000035	.0000055	.0000020
N	.0000160	.0000227	.0000104
NO	.0000002	.0000004	.0000001
N2	.0000001	.0000001	
NH3	.0000004	.0000074	.0000053
CH4	.0000327	.0000250	.0000471

EXCELLENT THERMOCLASTIC RESISTANCE AND CORROSION RESISTANCE

3

3

[illegible]

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

G.4

M6

TEMP. °K 2700.00 2800.00 2587.79

MOL. WT.

P	22.8528	22.8046	22.9300
e	99874	103565	95678
CO	- 441.03	- 402.77	
7	.357756	.359121	.356710
S	1.25562	1.25720	1.26172
E	2.09971	2.11328	2.08387
HF	714.66	751.42	673.30
	1210.77	1210.25	1211.30

CO	.0226113	.0225961	.0226511
CO2	.0016215	.0015614	.0016774
H2	.0067971	.0068251	.0067395
H2O	.0076499	.0078791	.0078124
O2	.0044733	.0044804	.0044635
OH	.0000029	.0000046	.0000017
H	.0000124	.0000175	.0000061
NO	.0000002	.0000003	.0000001
N	.0000001	.0000001	
NH3	.0001064	.0001016	.0001105
CH4	.0000034	.0000045	.0001163

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M7

C.2

TEMP. °K	3300.00	3400.00	3500.00	3600.00	3700.00	3800.00	3900.00
MOL. WT.	26.3047	26.2450	26.1777	26.0884	25.9776	25.8434	25.6826
P	38935	40151	41379	42620	43878	45158	46455
e	- 591.44	- 550.78	- 508.65	- 464.57	- 418.44	- 367.65	- 316.91
CV	.352206	.352954	.353779	.354635	.355358	.356036	.356763
γ	1.21750	1.21649	1.21564	1.21475	1.21401	1.21345	1.21486
S	2.11557	2.12770	2.13990	2.15231	2.16497	2.17794	2.19112
E	916.18	952.76	989.70	1027.23	1065.17	1103.96	1142.57
HF	1565.36	1561.34	1556.19	1549.71	1541.59	1531.69	1519.67

CO	.0132601	.0133350	.0134088	.0134923	.0135950	.0137142	.0138573
CO2	.0064301	.0063921	.0063492	.0062995	.0062389	.0061711	.0060962
H2	.0021196	.0021080	.0021017	.0021012	.0021055	.0021234	.0021452
H2O	.0106451	.0106399	.0106283	.0106031	.0105712	.0105247	.0104660
H2	.0052162	.0053160	.0053756	.0053146	.0053132	.0053112	.0053000
O2	.0000035	.0000059	.0000097	.0000154	.0000238	.0000354	.0000510
O	.0000024	.0000040	.0000066	.0000105	.0000162	.0000244	.0000359
OH	.0001231	.0001570	.0002223	.0002905	.0003734	.0004712	.0005974
H	.0000058	.0000085	.0001030	.0001266	.0001543	.0001864	.0002237
H2	.0000251	.0000361	.0000506	.0000695	.0000935	.0001230	.0001588
N	.0000016	.0000024	.0000034	.0000048	.0000066	.0000089	.0000120
CH4	.0000035	.0000034	.0000032	.0000031	.0000030	.0000030	.0000030

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.2

M7

TEMP. °K 3686.01

MOL. WT. 25.9945

43701

.355289

.21911

2.18318

1.059.63

1.542.83

.135794

.062481

.003196

.0015782

.0053134

.0002224

.000153

.003008

.001511

.000398

.000003

.000000

TEMP. °K

MOL. WT.

•

Cv

7

DE

HF

CO2

CO

H2O

H2

NO

CH4

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•

•

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.05

M0

TEMP. °K	2300.00	2200.00	2400.00	2500.00	2600.00	2700.00	2800.00
MOL. WT.	26.6364	26.6392	26.6321	26.6253	26.6156	26.6010	26.5797
P	5511	5270	5754	5996	6239	6482	6726
•	- 562.50	- 1016.56	- 947.94	- 912.97	- 877.67	- 841.65	- 805.23
CV	.337164	.335143	.339185	.340924	.342540	.344018	.345455
γ	1.22053	1.22565	1.22497	1.22936	1.23189	1.23065	1.21943
ε	2.10176	2.08654	2.11610	2.12070	2.14454	2.15806	2.17136
E	578.04	544.74	611.74	645.55	679.74	714.21	749.06
HF	1618.93	1619.85	1618.21	1617.06	1615.96	1614.62	1612.91

CO ₂	.015543	.0114735	.0116064	.0116895	.0117472	.0118013	.0118536
CO	.0075609	.0076410	.0075102	.0074296	.0073754	.0073265	.0072618
H ₂ O	.0028117	.0026915	.0025609	.0024606	.0024271	.0023803	.0023400
H ₂	.0104309	.0103513	.0104803	.0105564	.0106081	.0106495	.0106821
O ₂	.0053750	.00533753	.0053760	.0053765	.0053770	.0053777	.0053785
N ₂				.0000001	.0000001	.0000003	.0000008
NO				.0000001	.0000001	.0000002	.0000005
H	.0000000	.00000014	.0000002	.0000004	.0000006	.0000002	.00000018
OH	.0000000	.00000030	.0000008	.0000121	.0000179	.0000258	.0000362
HO	.0000000	.00000001	.00000005	.0000010	.0000020	.0000036	.0000062
H ₂ O ₂				.0000001	.0000001	.0000002	.0000003
CH ₄	.00000003	.00000015	.0000012	.0000010	.0000010	.0000009	.0000008

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

MB
0.05

TEMP. °K	2900.00	3000.00	3100.00	3200.00	3300.00	3400.00	3500.00
MOL. WT.	26.5497	26.5072	26.4491	26.3703	26.2658	26.1294	25.9549
P	6972	7219	7469	7723	7980	8244	8515
e	- 767.76	- 729.01	- 688.69	- 646.34	- 601.45	- 553.47	- 501.78
CV	346763	347935	349001	349974	350906	351520	352130
7	1.21837	1.21746	1.21675	1.21616	1.21579	1.21564	1.21576
S	2.18452	2.19766	2.21087	2.22431	2.23812	2.25244	2.26742
E	784.29	820.00	856.21	893.07	930.63	969.01	1008.27
MF	1610.65	1607.63	1503.57	1598.12	1590.88	1581.36	1569.06

CO	.0119068	.0119644	.0120295	.0121076	.0122038	.0123247	.0124771
CO2	.0072355	.0071972	.0071531	.0071037	.0070456	.0069749	.0068873
H2	.0023050	.0022774	.0022550	.0022408	.0022342	.0022372	.0022518
H2O	.0107000	.0107205	.0107251	.0107182	.0106983	.0106639	.0106129
N2	.0033793	.0033804	.0033814	.0033826	.0033837	.0033850	.0033866
O2	.0000017	.0000033	.0000064	.0000117	.0000204	.0000341	.0000545
CH	.0000010	.0000020	.0000037	.0000068	.0000118	.0000198	.0000321
HCN	.0000640	.0000952	.0001378	.0001944	.0002677	.0003607	.0004757
NO	.0000496	.0000666	.0000876	.0001139	.0001457	.0001842	.0002303
N	.0000103	.0000166	.0000252	.0000389	.0000570	.0000811	.0001124
H	.0000066	.0000099	.0000014	.0000022	.0000033	.0000049	.0000070
OH	.0000009	.0000007	.0000007	.0000007	.0000006	.0000006	.0000006

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.05

M6

TEMP. °K	3600.00	3700.00	3800.00	3900.00	3650.52
MOL. WT.	25.7370	25.4711	25.1570	24.7941	25.6094
P	8794	9085	9337	9702	8940
e	- 443.77	- 335.03	- 319.06	- 243.09	
CV	352634	352989	353197	352830	352834
Y	1.21610	1.21675	1.21771	1.21948	1.21639
Z	2.28319	2.29936	2.31741	2.33585	2.29148
S	1048.50	1089.54	1131.66	1174.15	1069.12
HF	1553.43	1553.91	1510.28	1482.06	1544.12
CO2	.0126674	.0129038	.0131821	.0135102	.0127603
H2	.0067728	.0066437	.0064870	.0063024	.0067143
H2O	.0022800	.0023220	.0023841	.0024628	.0022993
N2	.0105434	.0104553	.0103421	.0102071	.0105015
O2	.0053865	.0053510	.0053945	.0053990	.0053897
CO	.0000638	.0001236	.0001748	.0002378	.0001024
OH	.0000501	.0000759	.0001112	.0001583	.0000621
H	.0006148	.0007798	.0009700	.0011861	.0006945
NO	.0002855	.0003511	.0004292	.0005215	.0003172
HO	.0001516	.0001999	.0002565	.0003219	.0001748
CH3	.0000058	.0000135	.0000184	.0000246	.0000116
CH4	.0000006	.0000006	.0000006	.0000006	.0000006

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.1

MB

TEMP. °K	2300.00	2200.00	2400.00	2500.00	2600.00	2700.00	2800.00
MOL. WT.	26.6405	26.6429	26.6372	26.6320	26.6253	26.6151	26.6004
P	11723	11206	12241	12757	13275	13794	14314
e	- 984.20	-1016.47	- 949.83	- 914.92	- 879.76	- 844.28	- 808.19
CV	338474	336541	340522	342250	343810	345215	346669
7	1.22998	1.23213	1.22766	1.22564	1.22382	1.22233	1.22076
3	2.03469	2.02547	2.05904	2.07361	2.08740	2.10080	2.11392
E	575.26	541.88	609.04	642.94	677.17	711.60	746.40
MF	1618.03	1618.88	1617.40	1616.39	1615.49	1614.44	1613.15
CO	.0116489	.0115702	.0116991	.0117794	.0118342	.0118849	.0119327
CO2	.0074047	.0075425	.0074157	.0073372	.0072849	.0072378	.0071953
H2	.0025137	.0025910	.0024650	.0023873	.0023254	.0022900	.0022507
H2O	.0105267	.0104492	.0105749	.0106517	.0107009	.0107428	.0107770
O2	.0053745	.0053741	.0053749	.0053755	.0053758	.0053763	.0053769
O					.0000001	.0000002	.0000004
NO	.0000019	.0000010	.0000036	.0000066	.0000112	.0000001	.0000002
N	.0000024	.0000021	.0000054	.0000082	.0000122	.0000185	.0000294
NO2	.0000002	.0000001	.0000004	.0000007	.0000014	.0000015	.0000046
N2	.0000028	.0000032	.0000025	.0000020	.0000001	.0000001	.0000002
CH4	.0000001	.0000001			.0000021	.0000019	.0000018

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

43

0.1

TEMP. °K	2900.00	3000.00	3100.00	3200.00	3300.00	3400.00	3500.00
MOL. WT.	26.5800	26.5500	26.5113	26.4581	26.3875	26.2964	26.1791
P	14855	13355	15885	16418	16955	17500	18054
CV	- 771.77	- 735.75	- 695.06	- 654.94	- 613.10	- 565.18	- 522.76
Y	347573	349121	350193	351199	352074	352836	353565
Z	1.21936	1.21814	1.21713	1.21617	1.21540	1.21483	1.21447
L	2.12063	2.11958	2.11827	2.11650	2.11476	2.11309	2.11142
MF	781.50	816.99	852.83	889.17	926.05	963.48	1001.55
	1611.49	1602.55	1590.51	1576.76	1561.84	1546.42	1530.16

CO	51.977	51.20282	51.20804	51.21402	51.22107	51.22965	51.24023
CO2	37.560	37.1177	37.0797	37.0392	36.9942	36.9418	36.8790
H2O	33.265	33.2178	33.21644	33.21453	33.21342	33.21285	33.21312
N2	33.338	33.33232	33.33341	33.33366	33.33293	33.33114	33.32813
O2	33.373	33.35782	33.33707	33.31793	33.29395	33.26397	33.22797
H2	33.373	33.3116	33.2331	33.13355	33.0138	32.8766	32.7270
CH4	33.373	33.2671	33.1318	32.9633	32.7582	32.5166	32.2459
C2H6	33.373	33.2432	33.0873	32.81375	32.5189	32.1947	31.8402
C2H4	33.373	33.2317	33.06182	32.76771	32.44985	32.1042	31.7348
C2H2	33.373	33.2006	33.0010	32.70275	32.38405	32.0379	31.6608
HCN	33.373	33.2006	33.0010	32.70275	32.38405	32.0379	31.6608
HF	33.373	33.2006	33.0010	32.70275	32.38405	32.0379	31.6608
	33.373	33.2006	33.0010	32.70275	32.38405	32.0379	31.6608

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.1

M8

TEMP. °K	3600.00	3700.00	3800.00	3900.00	3708.47
MOL. WT.	26.1317	25.8496	25.6308	25.3724	25.8326
P	13621	19202	19800	20416	19252
e	- 473.32	- 420.55	- 353.84	- 303.49	
CV	354245	354799	355227	354628	354840
7	1.21421	1.21417	1.21438	1.21578	1.21418
S	2.21634	2.23232	2.24791	2.26358	2.23407
E	1040.40	1079.90	1120.41	1161.21	1083.29
HF	1572.68	1559.52	1543.48	1524.11	1558.29

CO	.0125329	.0126957	.0128882	.0131191	.0127108
CO2	.0066029	.0067081	.0065982	.0064663	.0066994
H2	.0021418	.0021634	.0021989	.0022466	.0021657
H2O	.0107578	.0106811	.0106050	.0105125	.0106754
N2	.0053794	.0053790	.0053785	.0053781	.0053789
O2	.0000422	.0000338	.0000926	.0001298	.0000659
OH	.0000250	.0000383	.0000568	.0000819	.0000396
H	.0004423	.0005649	.0007085	.0008745	.0005762
HO	.0001911	.0002338	.0002840	.0003429	.0002377
N	.0001101	.0001466	.0001907	.0002428	.0001501
NO	.0000609	.0000995	.0000129	.0000173	.0000098
CH4	.0000012	.0000012	.0000012	.0000012	.0000012

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.2

M8

TEMP. °K	2600.00	2700.00	2800.00	2900.00	3000.00	3100.00	3200.00
MOL. WT.	26.0353	26.0279	26.0177	26.0043	26.9837	26.9573	26.9214
P	30313	31496	32679	33864	35052	36243	37440
c	- 682.35	- 846.97	- 811.05	- 774.64	- 737.57	- 699.83	- 561.06
CV	346312	347765	349243	350526	351597	352611	353651
Y	1.22639	1.22458	1.22255	1.22063	1.21801	1.21765	1.21623
S	2.02457	2.03792	2.05098	2.06375	2.07631	2.08868	2.10098
E	672.42	707.38	742.32	777.51	813.04	848.78	884.95
MF	1013.71	1012.85	1011.92	1010.70	1009.19	1007.20	1004.62

CO	0.02065	0.020625	0.021255	0.021658	0.022077	0.022502	0.022972
CO2	0.070789	0.070353	0.069962	0.069607	0.069262	0.068933	0.068593
H2	0.021201	0.020843	0.020479	0.020157	0.019888	0.019659	0.019473
H2O	0.139175	0.139475	0.139809	0.140074	0.140293	0.140435	0.140517
O2	0.055737	0.055742	0.055747	0.055747	0.055756	0.055759	0.055762
N2	0.000001	0.000001	0.000002	0.000003	0.000007	0.000014	0.000025
CH4	0.000078	0.000129	0.000205	0.000302	0.000440	0.000608	0.000815
H	0.000078	0.000112	0.000157	0.000215	0.000289	0.000380	0.000493
HO	0.000000	0.000018	0.000031	0.000051	0.000082	0.000129	0.000195
CH3	0.000000	0.000001	0.000002	0.000003	0.000004	0.000007	0.000011
CH4	0.000048	0.000043	0.000040	0.000035	0.000035	0.000035	0.000032
CH3	0.000001	0.000001	0.000001	0.000001	0.000001	0.000001	0.000001

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

MB

0.2

TEMP. °K	3300.00	3400.00	3500.00	3600.00	3700.00	3800.00	3900.00
MOL. WT.	26.4744	26.4134	26.3352	26.2368	26.1147	25.9666	25.7894
P	38643	39855	41079	42319	43577	44858	46161
e	- 621.10	- 579.75	- 536.77	- 491.66	- 444.28	- 394.04	- 341.62
CV	334529	335273	336096	336946	337695	338311	338953
7	1.21501	1.21402	1.21319	1.21233	1.21163	1.21112	1.21063
S	2.11326	2.12559	2.13804	2.15073	2.16374	2.17709	2.19071
E	921.51	938.48	955.85	1033.86	1072.34	1111.71	1150.93
HF	1601.26	1596.92	1591.36	1584.33	1575.52	1564.74	1551.67
CO	.1123503	.0124130	.0124862	.0125794	.0126923	.0128246	.0129836
CO2	.0068231	.0067826	.0067358	.0066807	.0066128	.0065355	.0064428
H2	.0019331	.0019234	.0019193	.0019212	.0019285	.0019466	.0019731
H2O	.0113522	.0110451	.0110294	.0110039	.0109693	.0109201	.0108586
N2	.0053761	.0051757	.0053750	.0053737	.0053719	.0053695	.0053665
O2	.0000045	.0000077	.0000126	.0000199	.0000306	.0000454	.0000651
C	.0000027	.0000046	.0000075	.0000120	.0000184	.0000276	.0000403
CH	.0001339	.0001816	.0002416	.0003155	.0004052	.0005114	.0006358
H	.0000629	.0000791	.0000984	.0001212	.0001477	.0001786	.0002148
HC	.0000287	.0000413	.0000579	.0000794	.0001067	.0001400	.0001803
CH3	.0000016	.0000024	.0000034	.0000048	.0000067	.0000090	.0000121
CH4	.0000030	.0000030	.0000028	.0000027	.0000026	.0000026	.0000026

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.2

MB

TEMP. °K 3756.96

MOL. WT. 26.9333
P 44304

CV .358056
γ 1.21132
S 2.17130
E 1094.64
HF 1569.64

.0127650
.0065700
.0019373
.009432
.003705
.0000385
.0000233
.0004635
.0001648
.0001248
.0000079
.0000026

CO
CO2
H2
H2O
O2
O
OH
H
HO
N
NH3
CH4

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.3

48

TEMP. °K	3100.00	3200.00	3300.00	3400.00	3500.00	3600.00	3700.00
MOLE WT.	26.5804	26.5518	26.5148	26.4669	26.4054	26.3281	26.2320
P	62317	64348	66385	68428	70485	72559	74651
e	- 701.42	- 663.05	- 623.74	- 583.52	- 541.67	- 498.24	- 453.00
CV	.355244	.356293	.357148	.357839	.358714	.359681	.360538
γ	1.21934	1.21761	1.21609	1.21483	1.21371	1.21246	1.21136
Σ	2.04652	2.05868	2.07076	2.08281	2.09487	2.10709	2.11950
E	846.17	882.46	919.07	955.99	993.19	1031.01	1069.20
MF	1606.16	1604.10	1601.42	1597.56	1593.56	1587.99	1581.01
CO	.0124569	.0124976	.0125427	.0125951	.0126575	.0127323	.0128244
CO ₂	.0066782	.0066479	.0066162	.0065810	.0065410	.0064943	.0064374
H ₂	.0017443	.0017271	.0017135	.0017034	.0016976	.0016966	.0016994
H ₂ O	.0112674	.0112769	.0112799	.0112767	.0112665	.0112485	.0112233
H ₂	.0053735	.0053738	.0053736	.0053730	.0053720	.0053704	.0053681
O ₂	.0000000	.0000015	.0000028	.0000047	.0000078	.0000125	.0000193
O	.0000005	.0000010	.0000017	.0000029	.0000047	.0000075	.0000117
OH	.0000554	.0000780	.0001090	.0001480	.0001973	.0002583	.0003327
H	.0000274	.0000355	.0000452	.0000569	.0000707	.0000870	.0001059
HO	.0000106	.0000161	.0000230	.0000343	.0000482	.0000663	.0000894
H	.0000000	.0000009	.0000013	.0000019	.0000028	.0000039	.0000053
CH ₄	.0000000	.0000004	.0000005	.0000005	.0000004	.0000002	.0000000

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.3

M8

TEMP. °K	3800.00	3900.00	3777.91
MOL. WT.	26.1152	25.9749	26.1429
F	76770	78909	76300
g	- 405.39	- 356.49	361130
CV	361284	359034	1=21061
γ	1.21042	1.21230	2.12933
S	2.13215	2.14485	1099.51
E	1108.19	1146.63	1574.51
HF	1572.47	1562.12	
CO	0.129317	0.130599	0.129065
CO2	0.063732	0.062971	0.063881
H2	0.017108	0.017293	0.017075
H2O	0.111859	0.111381	0.111953
H2	0.053651	0.053612	0.053658
O2	0.000288	0.000418	0.000265
O	0.000175	0.000257	0.000161
OH	0.004213	0.005256	0.004004
H	0.001280	0.001536	0.001229
NO	0.001178	0.001524	0.001110
...	0.000072	0.000097	0.000068
NH3	0.000044	0.000044	0.000044
CH4			

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

MB

0.4

TEMP. °K	3200.00	3300.00	3400.00	3500.00	3600.00	3700.00	3800.00
MOL. WT.	26.5723	26.5409	26.5006	26.4407	26.3834	26.3022	25.2035
P	98317	101380	104446	107524	110617	113727	115864
e	- 663.04	- 623.95	- 583.94	- 542.93	- 500.31	- 456.14	- 409.89
CV	.359159	.359983	.360608	.361521	.362590	.363546	.364385
γ	1.22094	1.21913	1.21771	1.21636	1.21479	1.21336	1.21209
S	2.02475	2.03673	2.04868	2.06055	2.07253	2.08465	2.09693
E	881.11	917.91	954.95	992.17	1030.01	1068.18	1107.10
HF	1602.73	1600.45	1597.51	1593.76	1589.03	1583.08	1575.82
CO	.0127190	.0127588	.0128049	.0128597	.0129252	.0130057	.0130992
CO2	.0064190	.0063906	.0063591	.0063231	.0062813	.0062304	.0061751
H2	.0014920	.0014900	.0014707	.0014650	.0014632	.0014643	.0014725
H2O	.0115126	.0115162	.0115144	.0115070	.0114928	.0114727	.0114422
N2	.0053713	.0053710	.0053703	.0053692	.0053674	.0053648	.0053613
O2	.0000011	.0000019	.0000033	.0000055	.0000089	.0000138	.0000207
O	.0000007	.0000012	.0000020	.0000033	.0000053	.0000083	.0000125
OH	.0000676	.0000942	.0001281	.0001711	.0002244	.0002896	.0003675
H	.0000264	.0000336	.0000423	.0000526	.0000647	.0000788	.0000951
NO	.0000143	.0000212	.0000306	.0000431	.0000594	.0000803	.0001041
N	.0000007	.0000011	.0000016	.0000023	.0000033	.0000045	.0000061
H+3	.0000082	.0000076	.0000076	.0000072	.0000069	.0000066	.0000065
CH4	.0000001	.0000001	.0000001	.0000001	.0000001	.0000001	.0000001

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

48

G-4

TEMP. °A	3900.00	3786.59
MOL. WT.	20.0846	26.2177
P	120016	116444
C	- 363.02	
O	361106	354381
γ	1.21446	1.21221
S	2.10910	2.09528
E	1145.06	1101.87
TE	1597.00	1576.87

CO	132103	0130839
CO2	061059	0061812
H2	0014569	0014710
H2O	0114022	0114469
H2	0033966	0053619
O2	0000002	0000197
O	0001153	0000118
OF	0004596	0003563
FF	0001141	0000928
NO	0001377	0001024
NO2	0001082	0000059
HTS	0000065	0000065

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M9 0.05

TEMP. °K	2400.00	2500.00	2600.00	2700.00	2800.00	2900.00	3000.00
MOL. WT.	27.3586	27.3513	27.3404	27.3239	27.2995	27.2644	27.2140
P	5598	5834	6071	6308	6546	6786	7028
e	-1003.32	-968.43	-933.15	-897.30	-860.59	-822.79	-783.55
CV	338637	340390	342012	343493	344928	346228	347385
Z	1.21964	1.21805	1.21660	1.21538	1.21419	1.21316	1.21230
S	2.03455	2.05947	2.11330	2.12684	2.14018	2.15344	2.16674
E	610.12	643.95	678.15	712.65	747.55	782.90	818.78
HF	1672.17	1671.11	1670.04	1668.69	1666.91	1664.49	1661.16
CO	.0100107	.0100354	.0101345	.0101835	.0102324	.0102845	.0103439
CO2	.0084371	.0082669	.0082194	.0082760	.0082354	.0081952	.0081528
H2	.0019984	.0019290	.0018831	.0018433	.0018094	.0017811	.0017588
H2O	.0106343	.0107014	.0107424	.0107777	.0108038	.0108216	.0108304
H2	.0054566	.0054570	.0054575	.0054580	.0054587	.0054593	.0054601
O2		.0000001	.0000002	.0000006	.0000013	.0000028	.0000057
O			.0000001	.0000003	.0000006	.0000013	.0000026
OH	.0000060	.0000103	.0000184	.0000303	.0000480	.0000736	.0001095
H	.0000070	.0000107	.0000158	.0000227	.0000318	.0000436	.0000585
NO	.0000007	.0000014	.0000026	.0000047	.0000082	.0000136	.0000219
N		.0000001	.0000001	.0000002	.0000003	.0000006	.0000009
NH3		.0000007	.0000007	.0000006	.0000006	.0000006	.0000005
CH4							

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M9 0.05

TEMP. °K	3100.00	3200.00	3300.00	3400.00	3500.00	3600.00	3700.00
MOL. WT.	27.1440	27.0478	26.9186	26.7489	26.5317	26.2616	25.9355
P	7273	7521	7776	8037	8307	8588	8880
e	- 742.44	- 698.88	- 652.25	- 601.87	- 547.06	- 487.22	- 421.99
CV	348425	345359	350137	350772	351280	351658	351864
7	1.21165	1.21114	1.21088	1.21089	1.21120	1.21179	1.21272
S	2.18022	2.19404	2.20838	2.22342	2.23930	2.25615	2.27405
E	855.27	892.51	930.63	969.74	1009.90	1051.17	1093.34
HF	1656.58	1650.33	1641.91	1630.75	1616.26	1597.87	1575.04
CO	.0104152	.0105551	.0106206	.0107701	.0109616	.0112020	.0114956
CO2	.0031054	.0030484	.0029774	.0028868	.0027716	.0026272	.0024487
H2	.0017430	.0017344	.0017348	.0017456	.0017691	.0018073	.0018604
H2O	.0158285	.0158161	.0157903	.0157500	.0156932	.0156181	.0155246
N2	.0054609	.0054617	.0054625	.0054636	.0054653	.0054677	.0054712
O2	.0000110	.0000199	.0000345	.0000571	.0000901	.0001359	.0001964
O	.0000049	.0000089	.0000154	.0000257	.0000413	.0000639	.0000958
OH	.0001583	.0002230	.0003066	.0004120	.0005414	.0006967	.0008790
H	.0000772	.0001002	.0001285	.0001628	.0002044	.0002546	.0003149
NO	.0000340	.0000512	.0000747	.0001057	.0001455	.0001947	.0002536
N	.0000014	.0000022	.0000033	.0000049	.0000070	.0000099	.0000137
H+3	.0000005	.0000004	.0000004	.0000004	.0000004	.0000004	.0000004
CH4							

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.05

MS

TEMP. °K	3800.00	3900.00	4000.00	3706.95
MOL. WT.	25.5565	25.1269	24.6529	25.9109
P	9186	9506	9840	8901
e	- 351.18	- 275.18	- 193.96	
CV	.351909	.351360	.351145	.351873
γ	1.21400	1.21608	1.21811	1.21280
S	2.29289	2.31263	2.33315	2.27532
C	1136.52	1179.87	1223.67	1096.30
HF	1547.09	1515.45	1478.27	1573.30
CO	.0118449	.0122453	.0126946	.0115209
CO2	.0072424	.0070043	.0067392	.0074352
H2	.0019334	.0020231	.0021310	.0018648
H2O	.0104371	.0102693	.0101062	.0105173
H2	.0054761	.0054824	.0054904	.0054715
O2	.0002711	.0003598	.0004613	.0002011
CH	.0001338	.0001952	.0002671	.0000934
CH	.0010870	.0013211	.0015789	.0008925
H	.0003875	.0004742	.0005773	.0003195
H	.0003217	.0003968	.0004838	.0002581
H	.0000186	.0000249	.0000329	.0000140
NH3	.0000004	.0000005	.0000005	.0000004
CH4				

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M9

0.1

TEMP. °K	2400.00	2500.00	2600.00	2700.00	2800.00	2900.00	3000.00
MOL. WT.							
P	27.3632	27.2578	27.3504	27.3389	27.3221	27.2984	27.2641
e	11907	12410	12915	13421	13928	14437	14943
CV	-1005.30	-970.53	-935.45	-899.95	-863.80	-826.87	-788.93
γ	.33971	.34174	.34328	.34469	.34614	.34747	.34858
S	1.22251	1.22050	1.21869	1.21722	1.21567	1.21429	1.21310
E	2.02934	2.04384	2.05761	2.07101	2.08416	2.09711	2.10997
HF	617.43	641.33	675.56	710.01	744.84	780.01	815.60
	1671.55	1670.61	1669.74	1668.71	1667.39	1665.65	1663.32
CO	.0100005	.0101583	.0102063	.0102515	.0102950	.0103393	.0103875
CO2	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
H2	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
H2O	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
O2	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
N2	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
HF	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
H	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
O	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
N	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
OH	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
CH	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
CH2	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
CH3	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
CH4	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

19

0.1

TEMP. °K	3100.00	3200.00	3300.00	3400.00	3500.00	3600.00	3700.00
MOL. WT.	27.2171	27.1528	27.0667	26.9536	26.8977	26.8239	26.3974
P	15464	15985	16512	17049	17598	18161	18741
e	- 749.74	- 708.87	- 665.93	- 620.47	- 571.99	- 519.89	- 463.84
Cv	.369635	.350026	.351467	.352179	.352840	.353430	.353874
γ	1.21213	1.21122	1.21052	1.21004	1.20981	1.20971	1.20987
z	2.12261	2.11378	2.14898	2.16255	2.17659	2.19126	2.20664
z	351.61	388.12	925.40	963.32	1002.01	1041.62	1082.02
TF	1660.12	1655.93	1650.26	1642.80	1633.11	1620.75	1605.24
CO	.0064420	.0050078	.0105891	.0206919	.0108221	.0109859	.0111905
CO2	.0080337	.0080098	.0079579	.0078941	.0078143	.0077128	.0075899
H2	.0016642	.0016515	.0016447	.0016449	.0016536	.0016722	.0017007
H2O	.0125251	.0109224	.0109100	.0098870	.0108520	.0108036	.0107420
CH4	.0054504	.0054585	.0054553	.0054579	.0054573	.0054566	.0054559
O2	.0010033	.0010096	.000109	.0000284	.0000457	.0000707	.0001052
OH	.0000024	.0000043	.0000070	.0000127	.0000206	.0000223	.0000491
H	.0001119	.0001580	.0002180	.0002942	.0003890	.0005042	.0006417
N2	.0000522	.0000676	.0000865	.0001092	.0001364	.0001689	.0002075
NO	.0000241	.0000364	.0000534	.0000761	.0001058	.0001433	.0001894
N	.0000010	.0000016	.0000024	.0000035	.0000049	.0000070	.0000096
CH	.0000010	.0000009	.0000009	.0000009	.0000009	.0000006	.0000008

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

C.1

M9

TEMP. °K 3800.00 3900.00 4000.00 3777.39

MO. WT.

26.1275 25.8126 25.4545 26.1920
 1934. 19962 20606 19204
 - 403.35 - 333.79 - 269.56
 354.74 353450 353460 354121
 2.2131 1.21196 1.21313 1.21019
 2.2273 2.23951 2.25703 2.21902
 1.23.48 1.65.24 1297.73 1.14.00
 1950.11 1903.82 1937.34 1991.00

CV

Y

Z

MF

CO

CO2

H2O

H2

O2

N2

Ar

CH4

C2H6

C3H8

iC4H10

nC4H10

0.14244 0.17256 0.120978 0.113755
 0.074431 0.072686 0.070676 0.074795
 0.017443 0.014006 0.018712 0.017329
 0.006010 0.015557 0.0104510 0.016418
 0.004055 0.004554 0.004560 0.004355
 0.001400 0.002004 0.002730 0.001588
 0.001721 0.001333 0.001457 0.001064
 0.001111 0.000841 0.001111 0.000830
 0.000634 0.000576 0.000716 0.000423
 0.000244 0.000376 0.000350 0.000309
 0.000130 0.000174 0.000250 0.000122
 0.000004 0.000009 0.000059 0.000008

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M9

O.2

TEMP. °K	2800.00	2900.00	3000.00	3100.00	3200.00	3300.00	3400.00
MOL. WT.	27.3400	27.3243	27.3007	27.2693	27.2263	27.1692	27.0943
P	31804	32961	34122	35287	36459	37639	38829
e	- 867.10	- 820.60	- 792.37	- 755.33	- 716.08	- 675.44	- 633.10
CV	348732	350015	351085	352093	353118	353977	354691
γ	1.21765	1.21580	1.21419	1.21284	1.21146	1.21028	1.20923
S	2.02273	2.03553	2.04814	2.06060	2.07305	2.08554	2.09817
E	747.74	775.97	811.56	847.40	883.72	920.50	957.78
HF	1666.58	1665.52	1663.70	1661.51	1658.62	1654.80	1649.79

CO	.0104519	.0104891	.0105289	.0105716	.0106211	.0106800	.0107524
CO2	.0060022	.0079703	.0079385	.0079055	.0078715	.0078321	.0077852
H2	.0015679	.0015411	.0015188	.0015003	.0014859	.0014759	.0014703
H2O	.0110540	.0110752	.0110918	.0111013	.0111048	.0111011	.0110897
N2	.0054557	.0054557	.0054562	.0054562	.0054560	.0054554	.0054543
O2	.0000003	.0000006	.0000012	.0000024	.0000044	.0000078	.0000133
O	.0000001	.0000003	.0000006	.0000011	.0000020	.0000036	.0000061
OH	.0000236	.0000363	.0000541	.0000786	.0001112	.0001539	.0002085
H	.0000138	.0000188	.0000252	.0000332	.0000430	.0000548	.0000691
H2O	.0000041	.0000068	.0000109	.0000171	.0000259	.0000382	.0000547
N	.0000002	.0000003	.0000005	.0000007	.0000011	.0000016	.0000024
NH3	.0000027	.0000000	.0000024	.0000023	.0000021	.0000020	.0000020

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION:

M9

O.2

TEMP. °K	3500.00	3600.00	3700.00	3800.00	3900.00	4000.00	3939.60
MOL. WT.	26.9975	26.8749	26.7223	26.5374	26.3174	26.0611	26.4547
p	40034	41259	42506	43780	45079	46415	44291
c	- 508.78	- 541.91	- 492.27	- 439.23	- 389.72	- 324.15	- 357.133
CV	355469	356256	356936	357447	358123	358749	357133
7	1.20258	1.20761	1.20735	1.20689	1.20654	1.20295	1.20729
5	2.11101	2.12420	2.13781	2.15189	2.16632	2.18142	2.15756
E	905.55	1024.09	1079.22	1112.29	1152.22	1194.26	1129.15
HF	1043.21	1035.25	1024.55	1011.91	1006.49	1000.14	1006.15
CO ₂	0.000024	0.009544	0.010950	0.012627	0.014545	0.017729	0.013382
CO	0.077234	0.076587	0.075712	0.074684	0.073447	0.071986	0.074221
H ₂ O	0.001704	0.014769	0.014893	0.015124	0.015444	0.015864	0.015239
H ₂	0.000000	0.010404	0.010019	0.009495	0.008852	0.008079	0.009256
HO	0.004321	0.004505	0.004478	0.004445	0.004407	0.004366	0.004430
O ₂	0.000000	0.000343	0.000500	0.000764	0.001079	0.001472	0.000879
N ₂	0.000000	0.000106	0.000240	0.000357	0.000516	0.000731	0.000415
Ar	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
HF	0.000000	0.001062	0.001291	0.001571	0.001901	0.002282	0.001699
HCN	0.000000	0.001047	0.001398	0.001825	0.002332	0.002920	0.002015
CH ₄	0.000000	0.000048	0.000067	0.000091	0.000121	0.000160	0.000102
CH ₃	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

MS

0.3

TEMP. °K	3200.00	3300.00	3400.00	3500.00	3600.00	3700.00	3800.00
MOL. WT.	27.2101	27.2153	27.1566	27.0807	26.9845	26.8643	26.7179
P	82718	54716	86723	68746	70790	72857	74955
e	- 718.75	- 676.90	- 637.71	- 595.01	- 550.18	- 503.13	- 453.34
CV	.355801	.356645	.357316	.358155	.359069	.359862	.360526
γ	1.21297	1.21148	1.21024	1.20917	1.20799	1.20698	1.20616
S	.03162	2.04387	2.05614	2.06851	2.08111	2.09402	2.10724
E	881.17	917.95	955.12	992.65	1030.87	1069.59	1109.17
HF	1658.72	1655.57	1651.7	1646.57	1640.04	1631.79	1621.68
CO	.0107770	.0108260	.0108856	.0109590	.0110498	.0111635	.0112989
CO2	.0077041	.0076703	.0076307	.0075832	.0075255	.0074533	.0073688
H2	.0043073	.0042972	.0042904	.0042860	.0042822	.0042792	.0042767
H2O	.0112099	.0112091	.0112082	.0112085	.0112072	.0112067	.0112061
N2	.0054542	.0054534	.0054521	.0054502	.0054476	.0054441	.0054397
O2	.0000027	.0000049	.0000063	.0000137	.0000218	.0000335	.0000497
OH	.0000013	.0000022	.0000038	.0000062	.0000099	.0000153	.0000229
H	.0000903	.0001252	.0001699	.0002203	.0002958	.0003803	.0004805
HO	.0000308	.0000392	.0000494	.0000614	.0000757	.0000923	.0001119
N	.0000215	.0000317	.0000457	.0000641	.0000950	.0001381	.0001951
NH3	.0000009	.0000013	.0000019	.0000028	.0000039	.0000053	.0000072
CH4	.0000036	.0000034	.0000033	.0000032	.0000030	.0000030	.0000029

9

52

EMP. NO.	390.00	400.00	3869.45
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26.3424	26.3357	26.5952
77079	79244	76427
- 431.61	- 346.67	
1358261	358588	359282
1.20811	2.20810	1.20720
2.12265	2.12450	2.11652
1148.31	1198.61	1136.40
1608.40	1594.71	1613.40

014622 • 016567
017271 • 007145
017333 • 013527
017422 • 010691
0054346 • 0054286
0000711 • 0009989
0000334 • 0000475
0000979 • 0007351
0001347 • 0001613
0001994 • 0002516
0000097 • 0000128
0000029 • 0000030

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M9

0.4

TEMP. °K	3300.00	3400.00	3500.00	3600.00	3700.00	3800.00	3900.00
MOL. WT.	27.2436	27.1944	27.1303	27.0491	26.9475	26.8234	26.6741
P	99980	101993	105022	108070	111139	114241	117359
e	- 575.74	- 639.07	- 597.15	- 553.34	- 507.61	- 459.47	- 410.29
CV	355541	360154	361036	362057	362953	363719	364536
γ	1.21468	1.21320	1.21190	1.21039	1.20903	1.20786	1.21022
z	2.01050	2.02262	2.03475	2.04707	2.05960	2.07239	2.08517
E	916.90	954.05	991.56	1029.74	1068.39	1107.82	1146.40
W	1855.04	1551.95	1247.59	953.03	655.00	356.35	55.53
CO	.0109931	.0110451	.0111091	.0111881	.0112869	.0114048	.0115467
CO2	.0074935	.0074984	.0074162	.0073650	.0073011	.0072351	.0071863
H2	.0011109	.0011104	.0011013	.0011019	.0011056	.0011160	.0011324
H2O	.0114759	.0114750	.0114645	.0114476	.0114249	.0113926	.0113516
H2	.0054515	.0054500	.0054479	.0054450	.0054410	.0054360	.0054270
O2	.0000025	.0000059	.0000098	.0000157	.0000244	.0000363	.0000525
O	.0000116	.0000027	.0000044	.0000070	.0000103	.0000164	.0000240
OH	.0001080	.0001469	.0001959	.0002567	.0003308	.0004191	.0005230
H	.0000290	.0000365	.0000454	.0000558	.0000681	.0000825	.0000992
H2	.0000264	.0000409	.0000576	.0000792	.0001067	.0001406	.0001815
N2	.0000004	.0000016	.0000025	.0000035	.0000045	.0000061	.0000081
CH4	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000

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PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M10

0.05

TEMP. °K	1600.00	1700.00	1800.00	1900.00	2000.00	2100.00	2200.00
MOL. WT.							
P	24.4944	24.4374	24.4165	24.4075	24.4030	24.3992	24.3973
e	4174	4444	4711	4977	5242	5507	5772
CV	-1036.74	-1001.59	-967.23	-933.08	-898.96	-864.73	-830.54
γ	.320555	.323640	.326718	.329503	.332142	.334629	.336865
S	1.26488	1.26125	1.25779	1.25469	1.25192	1.24934	1.24700
E	2.07361	2.09493	2.11456	2.13332	2.15052	2.16723	2.18321
HF	354.11	327.13	419.56	452.02	484.54	517.63	550.79
	1447.77	1445.67	1443.76	1442.07	1440.60	1439.34	1438.11
CO	.0160392	.0163491	.0165792	.0167654	.0169197	.0170522	.0171659
CO2	.0060210	.0057595	.0055467	.0053676	.0052165	.0050867	.0049739
H2	.0062453	.0060555	.0058689	.0057006	.0055546	.0054271	.0053152
H2O	.0079074	.0081625	.0083734	.0085520	.0087030	.0088233	.0089457
H2	.0045652	.0045718	.0045746	.0045760	.0045769	.0045777	.0045781
O2							
OH							
H	.0000001	.0000001	.0000003	.0000001	.0000002	.0000004	.0000006
N2				.0000007	.0000013	.0000024	.0000042
N							
NH3	.0000114	.0000090	.0000073	.0000060	.0000051	.0000044	.0000039
CH4	.0000360	.0000134	.0000055	.0000025	.0000013	.0000007	.0000004

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M10

0.05

TEMP. °K	2300.00	2400.00	2500.00	2600.00	2700.00	2800.00	2900.00
MCL. WT.	24.3942	24.3901	24.3841	24.3764	24.3651	24.3496	24.3288
P	6036	6300	6564	6829	7095	7361	7628
e	- 795.84	- 761.19	- 725.99	- 690.57	- 654.74	- 618.32	- 581.22
CV	.338264	.340876	.342586	.344196	.345680	.347125	.348457
γ	1.24211	1.24218	1.24153	1.24000	1.23869	1.23740	1.23624
S	2.19856	2.21284	2.22768	2.24158	2.25510	2.26834	2.28136
E	584.19	618.00	651.87	686.10	720.58	755.38	790.48
HF	1437.01	1436.17	1434.85	1433.66	1432.32	1430.71	1428.73
CO	.0172660	.0173302	.0174327	.0175027	.0175668	.0176261	.0176823
CO2	.0048753	.0048129	.0047133	.0046469	.0045878	.0045357	.0044890
H2	.0052169	.0051540	.0050539	.0049858	.0049253	.0048719	.0048241
H2O	.0090441	.0091060	.0092045	.0092686	.0093238	.0093699	.0094069
N2	.0045785	.0045790	.0045796	.0045802	.0045811	.0045820	.0045829
O2	.0000017	.0000017	.0000017	.0000017	.0000017	.0000017	.0000017
OH	.0000017	.0000017	.0000017	.0000017	.0000017	.0000017	.0000017
H	.0000017	.0000017	.0000017	.0000017	.0000017	.0000017	.0000017
NO	.0000017	.0000017	.0000017	.0000017	.0000017	.0000017	.0000017
N	.0000017	.0000017	.0000017	.0000017	.0000017	.0000017	.0000017
NH3	.0000017	.0000017	.0000017	.0000017	.0000017	.0000017	.0000017
CH4	.0000017	.0000017	.0000017	.0000017	.0000017	.0000017	.0000017

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	TEMP. °K	2000.00	3100.70	3200.00	3018.97
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PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M10

0.1

TEMP. °K	2300.00	2400.00	2500.00	2600.00	2700.00	2800.00	2900.00
MOL. WT.	24.4038	24.3987	24.3930	24.3875	24.3792	24.3681	24.3542
P	12867	13432	13996	14560	15126	15692	16259
e	- 797.24	- 762.97	- 727.40	- 692.09	- 656.51	- 620.44	- 583.89
CV	342217	342251	343394	345499	346909	348364	349686
Z	1.44741	1.44505	1.44302	1.44116	1.43963	1.43801	1.43655
Y	2.12629	2.15062	2.16542	2.17927	2.19273	2.20562	2.21865
E	581.53	615.43	649.42	683.72	718.21	753.02	788.05
MF	1435.72	1454.33	1473.81	1493.60	1513.71	1533.46	1553.95

CO	0.173324	0.174955	0.176502	0.178037	0.179553	0.177414	0.177931
CO2	0.047441	0.046832	0.045955	0.044966	0.043828	0.042418	0.040865
H2	0.050077	0.050182	0.049221	0.048363	0.047492	0.046469	0.045304
H2O	0.091742	0.092243	0.092520	0.092592	0.0924504	0.091971	0.091335
N2	0.113757	0.1145764	0.115374	0.116177	0.1169785	0.117793	0.118577
N						0.000001	0.000001
NO						0.000002	0.000002
NO2						0.000178	0.000273
H	0.000002	0.000002	0.000003	0.000005	0.000010	0.000017	0.000026
HF	0.000076	0.000069	0.000057	0.000041	0.000025	0.000012	0.000004
CH4	0.000011	0.000007	0.000004	0.000003	0.000002	0.000001	0.000000

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

C.I

M10

TEMP. °C	3000.00	3100.00	3200.00	3028.46
MOL. WT.	24.3324	24.3078	24.2741	24.3266
P	15825	17299	17974	16990
•	- 545.63	- 505.73	- 465.05	
CV	355962	351970	353047	351185
7	1.23527	1.22417	1.23210	1.23474
S	2.23125	2.24367	2.25599	2.23190
E	823.45	857.07	895.13	832.56
HF	1427.16	1424.89	1422.06	1426.56
CO	78441	9178932	9179429	9178989
CO2	543249	5042575	5042525	5043125
H2O	546612	5346252	5345937	5346590
H2	25076	3395907	3395003	3395751
CH4	24413	2711423	2706577	2704810
C2H2	1000	1000000	1000000	1000000
C2H4	1000	1000000	1000000	1000000
C2H6	1000	1000000	1000000	1000000
C3H8	1000	1000000	1000000	1000000
C4H10	1000	1000000	1000000	1000000
C4H8	1000	1000000	1000000	1000000
C4H6	1000	1000000	1000000	1000000
C5H12	1000	1000000	1000000	1000000
C5H10	1000	1000000	1000000	1000000
C5H8	1000	1000000	1000000	1000000
C6H14	1000	1000000	1000000	1000000
C6H12	1000	1000000	1000000	1000000
C6H10	1000	1000000	1000000	1000000
C6H8	1000	1000000	1000000	1000000
C7H16	1000	1000000	1000000	1000000
C7H14	1000	1000000	1000000	1000000
C7H12	1000	1000000	1000000	1000000
C7H10	1000	1000000	1000000	1000000
C8H18	1000	1000000	1000000	1000000
C8H16	1000	1000000	1000000	1000000
C8H14	1000	1000000	1000000	1000000
C8H12	1000	1000000	1000000	1000000
C9H20	1000	1000000	1000000	1000000
C9H18	1000	1000000	1000000	1000000
C9H16	1000	1000000	1000000	1000000
C9H14	1000	1000000	1000000	1000000
C10H22	1000	1000000	1000000	1000000
C10H20	1000	1000000	1000000	1000000
C10H18	1000	1000000	1000000	1000000
C10H16	1000	1000000	1000000	1000000
C10H14	1000	1000000	1000000	1000000

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M10

0.2

TEMP. °F.	190	200	2100.00	2200.00	2300.00	2400.00	2500.00
MOL. WT.	24.4705	24.4976	24.4609	24.4409	24.4280	24.4196	24.4105
P	24.209	25542	26859	28166	29455	30752	32037
C	- 747.17	- 904.23	- 1059.02	- 1213.94	- 1368.15	- 1522.23	- 1676.57
CV	3342.22	3366.49	3392.12	3418.71	3445.94	3472.75	3499.36
γ	1.20730	1.26051	1.25654	1.25298	1.25046	1.24748	1.24492
S	2.03019	2.01060	2.03581	2.05212	2.06761	2.08201	2.09693
E	- 3.13	474.01	508.30	542.46	576.38	610.69	645.05
TF	1476.17	1435.11	1434.26	1433.35	1432.49	1431.89	1430.89

CO	0.173331	0.172934	0.174513	0.175747	0.176732	0.177422	0.178416
CO ₂	0.049310	0.047719	0.046435	0.045363	0.044425	0.043842	0.042903
H ₂ O	0.081905	0.049915	0.049089	0.048256	0.047464	0.046962	0.046101
H ₂	0.089965	0.091490	0.092743	0.093803	0.094735	0.095515	0.096254
O ₂	0.054578	0.045569	0.045621	0.045654	0.045677	0.045694	0.045717
OH							
H	0.000001	0.000001	0.000002	0.000004	0.000008	0.000015	0.000028
N ₂	0.000003	0.000006	0.000011	0.000019	0.000031	0.000050	0.000077
N						0.000001	0.000002
NO						0.000170	0.000135
NO ₂						0.000036	0.000023

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M10

0.2

TEMP. °K	2600.00	2700.00	2800.00	2900.00	3000.00	3100.00	3200.00
H ₂ O	24.4000	24.3481	24.2874	24.2188	24.1419	24.0569	23.9639
N ₂	33.222	34.012	34.803	35.594	36.385	37.176	37.967
O ₂	0.0345	0.0742	0.1139	0.1536	0.1933	0.2330	0.2727
CO	0.0072	0.0115	0.0158	0.0201	0.0244	0.0287	0.0330
CO ₂	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H ₂	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
OH	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
NO	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
HF	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

CO ₂	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H ₂ O	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
N ₂	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
O ₂	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CO	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CO ₂	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H ₂	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
OH	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
NO	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
HF	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.2

M10

3034.41

TEMP. °C

24.2584
38516

WOL. WT.

0.553741
0.022467
2.115017
312.28
1.115.29

e
CV
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0.01261
0.040313
0.043609
0.009540
0.45763
0.00001
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0.000336
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PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M10

0.3

TEMP. °K	2400.00	2500.00	2600.00	2700.00	2800.00	2900.00	3000.00
MOL. WT.	24.4548	24.4371	24.4258	24.4202	24.4110	24.4050	24.3980
P	52969	55184	57377	59572	61764	63947	66143
Q	- 704.92	- 729.21	- 695.53	- 657.87	- 621.76	- 585.38	- 548.51
CV	348337	349962	351269	352356	353844	355109	356094
Y	1.25056	1.24763	1.24502	1.24306	1.24061	1.23840	1.23652
S	2.03602	2.05110	2.06511	2.07857	2.09170	2.10447	2.11693
E	666.25	641.14	676.08	711.02	746.35	781.75	817.62
HF	1428.12	1427.30	1426.57	1425.86	1425.08	1424.11	1423.12

CO	0180614	0151643	0182275	0132851	0183354	0183774	0184236
CO2	0040420	0039510	0038933	0038415	0037961	0037575	0037194
H2	0000114	0000240	0001876	0041425	0041018	0040617	0040333
H2O	0000710	0009622	0100161	0100087	0101117	0101453	0101793
N2	0045533	0045633	0045623	0045654	0045608	0045636	0045694
O2	0000014	0000022	0000036	0000062	0000099	0000091	0000091
...	0000037	0000056	0000094	0000121	0000171	0000152	0000127
...	0000001	0000002	0000003	0000005	0000009	0000015	0000024
...	0000015	0000028	0000263	0000001	0000001	0000002	0000003
CH4	0000106	0000069	0000046	0000243	0000225	0000233	0000202
			0000046	0000033	0000024	0000018	0000014

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.3

MIC

TEMP. °K 3100.00 3200.00 3023.77

MOL. WT.

P 24.3740 24.3540 24.3829
 e 58333 70528 66884
 CV - 511.40 - 473.65 .356425
 T 357072 .358150 1.23594
 S 1.23490 1.23314 2.12109
 E 2.12911 2.14108 829.71
 HF 853.41 889.60 1422.71
 1421.82 1420.26

CO
 CO2
 H2
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 CH4

.0184622 .0185020 .0184375
 .0036374 .0036570 .0037079
 .0040040 .0039801 .0040235
 .0102031 .0102226 .0101835
 .0045699 .0045710 .0045699
 .0000001 .0000002 .0000001
 .0000002 .0000004 .0000001
 .0000330 .0000465 .0000259
 .0000417 .0000540 .0000348
 .0000038 .0000058 .0000029
 .0000005 .0000008 .0000004
 .0000202 .0000003 .0000197
 .0000011 .0000008 .0000013

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

N10

0.4

TEMP. °K	2600.00	2700.00	2800.00	2900.00	3000.00	3100.00	3200.00
MOL. WT.	24.4665	24.4518	24.4398	24.4349	24.4145	24.4019	24.3829
P	87656	90974	94262	97568	100392	104172	107471
e	- 692.68	- 656.79	- 620.42	- 583.83	- 546.89	- 509.71	- 471.95
CV	351436	355400	356907	358142	359016	359919	360990
Y	1.24923	1.24717	1.24443	1.24194	1.23988	1.23809	1.23609
S	2.02819	2.04174	2.05496	2.06779	2.08033	2.09249	2.10446
E	672.95	706.26	743.97	779.56	815.54	851.97	888.44
HF	1422.56	1421.99	1421.35	1420.50	1419.74	1418.03	1417.39
CO	.0185712	.0186306	.0186905	.0187189	.0187659	.0188013	.0188389
CO2	.0035269	.0034773	.0034347	.0034001	.0033632	.0033241	.0032838
H2	.0057777	.0037425	.0037096	.0036740	.0036535	.0036257	.0035998
H2O	.0103806	.0104191	.0104696	.0104989	.0105394	.0105792	.0105747
H2	.0045516	.0045546	.0045568	.0045549	.0045605	.0045611	.0045625
O2							
OH							
H	.0000032	.0000093	.0000084	.0000135	.0000001	.0000001	.0000002
N2	.0000064	.0000093	.0000130	.0000179	.0000194	.0000283	.0000401
N	.0000002	.0000004	.0000038	.0000012	.0000021	.0000319	.0000414
HN3	.0000001	.0000001	.0000001	.0000002	.0000003	.0000033	.0000049
CH4	.0000436	.0000432	.0000377	.0000417	.0000334	.0000365	.0000307
CH+	.0000107	.0000075	.0000056	.0000041	.0000031	.0000333	.0000301
						.0000024	.0000019

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.4

M10

3029.13

TEMP. °K

MOL. WT.

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101843

.359276

1.23933

2.08391

826.46

1419.46

P

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CV

Y

S

E

MF

CO

CO2

H2

H2O

N2

O2

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CH4

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.0045612

.0000001

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.0000262

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222

155

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

W12

0.05

TEMP. °K	2200.00	2300.00	2400.00	2500.00	2600.00	2700.00	2800.00
MOL. WT.	23.6290	23.6257	23.6215	23.6154	23.6080	23.5974	23.5829
P	5969	6242	6515	6788	7061	7335	7610
e	- 741.50	- 706.99	- 672.34	- 637.15	- 601.74	- 565.93	- 529.57
CV	336926	338927	340935	342945	344962	346975	348987
7	1.25435	1.25245	1.25047	1.24850	1.24653	1.24455	1.24257
8	2.21011	2.23145	2.24569	2.26057	2.27446	2.28798	2.30120
E	552.55	585.90	619.78	653.67	687.90	722.38	757.16
HF	1355.39	1349.29	1346.47	1347.17	1346.00	1344.67	1343.10
CO	.0190329	.0191904	.0191932	.0192526	.0193036	.0194228	.0194800
CO2	.0040509	.0029552	.0038947	.0037982	.0037340	.0036771	.0036273
H2	.0065177	.0064229	.0063621	.0062655	.0061988	.0061396	.0060869
H2O	.0080765	.0081719	.0082320	.0083277	.0083901	.0084442	.0084895
H2	.0046315	.0046318	.0046324	.0046333	.0046338	.0046347	.0046359
O2							.0000001
O						.0000001	.0000001
N2	.0000007	.0000014	.0000026	.0000046	.0000079	.0000130	.0000205
N	.0000047	.0000078	.0000125	.0000192	.0000287	.0000414	.0000563
NO		.0000001	.0000001	.0000003	.0000006	.0000010	.0000018
NO2					.0000001	.0000002	.0000002
HT3	.0000053	.0000048	.0000043	.0000026	.0000037	.0000034	.0000032
CH4	.0000009	.0000005	.0000003	.0000002	.0000002	.0000001	.0000001

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M12

0.05

TEMP. °K 2900.00 3000.00 2843.74

MOL. WT.
 p 23.5640 23.5377 23.5742
 e 7886 8163 7742
 - 452.58 - 454.79
 CV 346351 346783 347876
 γ 1.24340 1.24236 1.24299
 S 2.31415 2.32699 2.30755
 E 792.21 827.61 774.21
 HF 1341.17 1329.80 1342.21

CO 0195337 0195809 0195066
 CO2 0035825 0035426 0036046
 H2 0060389 0059973 0060529
 H2O 0085264 0085557 0085088
 O2 0046366 0046387 0046383
 O 0000002 0000003 0000001
 OH 0000003 0000006 0000002
 H 0003141 0001457 0000254
 N2 0008002 0001081 0000584
 NO 0000029 0000047 0000023
 NH3 0000005 0000008 0000004
 CH4 0000036 0000029 0000003
 C2H6 0000001 0000001 0000001

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M12 0.1

TEMP. °K	1500.00	1600.00	1700.00	1800.00	1900.00	2000.00	2100.00
MOL. WT.	25.1161	24.2924	23.9229	23.7676	23.7004	23.6696	23.6539
P	8364	9090	9747	10366	10959	11561	12151
e	-1016.30	-962.94	-920.18	-882.51	-846.97	-812.07	-777.46
CV	322257	323716	325029	32659	331193	333726	335209
γ	1.27427	1.27470	1.27245	1.26913	1.26572	1.26248	1.25930
S	1.99568	2.03417	2.06010	2.08163	2.10089	2.11874	2.13562
E	284.81	337.60	379.02	415.14	449.30	482.79	516.23
HF	1356.49	1356.51	1355.35	1353.89	1352.46	1351.18	1350.01
CO	.0161825	.0174133	.0180901	.0184751	.0187240	.0189007	.0190397
CO2	.0056041	.0050797	.0047332	.0044889	.0043006	.0041512	.0040256
H2	.0061499	.0066581	.0068024	.0067697	.0066739	.0065666	.0064618
H2O	.0067612	.0071549	.0074383	.0076550	.0078333	.0079783	.0081019
H2	.0044780	.0045554	.0045928	.0046098	.0046180	.0046223	.0046248
O2							
O							
OH							
H							
NO							
N							
CH3	.0000330	.0000296	.0000252	.0000212	.0000179	.0000153	.0000134
CH4	.0000032	.0000242	.0000190	.0000532	.0000251	.0000128	.0000070

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M12 0.1

TEMP. °K	2200.00	2300.00	2400.00	2500.00	2600.00	2700.00	2800.00
MOL. WT.	23.6448	23.6362	23.6329	23.6263	23.6208	23.6126	23.6021
P	12739	13322	13907	14489	15073	15657	16242
e	- 742.84	- 708.26	- 673.55	- 638.37	- 603.06	- 567.49	- 531.46
CV	.338408	.340322	.342347	.344040	.345501	.347024	.348484
γ	1.25644	1.25425	1.25189	1.24985	1.24799	1.24644	1.24481
S	2.15172	2.16710	2.18136	2.19625	2.21010	2.22353	2.23663
z	549.79	583.29	617.35	651.40	685.71	720.22	755.03
HF	1348.96	1347.97	1347.26	1346.11	1345.12	1344.06	1342.84
CO	.0191946	.0192535	.0193162	.0194147	.0194804	.0195432	.0195946
CO2	.0039181	.0038241	.0037649	.0036701	.0036074	.0035517	.0035027
H2	.0063652	.0062775	.0062214	.0061298	.0060662	.0060101	.0059601
H2O	.0082036	.0083022	.0083610	.0084553	.0085166	.0085703	.0086160
H2	.0046264	.0046276	.0046266	.0046301	.0046304	.0046313	.0046322
O2							
OH	.0000005	.0000010	.0000018	.0000032	.0000055	.0000091	.0000001
H	.0000032	.0000054	.0000086	.0000132	.0000196	.0000284	.0000400
HO			.0000001	.0000002	.0000004	.0000007	.0000012
N					.0000001	.0000001	.0000002
NH3	.0000119	.0000106	.0000097	.0000080	.0000082	.0000076	.0000072
CH4	.0000041	.0000025	.0000016	.0000010	.0000007	.0000005	.0000004

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M12

0.1

TEMP. °K	2900.00	3000.00	2854.47
MOL. WT.	23.5895	23.5701	23.5955
P	16827	17415	16560
e	- 494.97	- 457.87	
CV	.349818	.351010	.349226
γ	1.24333	1.24203	1.24398
ε	2.24944	2.25201	2.24364
E	790.04	825.40	774.07
HF	1341.39	1339.65	1342.07

CO	.0196441	.0196931	.0196222
CO2	.0034295	.0034201	.0034784
H2	.0059139	.0058754	.0059345
H2O	.0086538	.0086859	.0086376
N2	.0046326	.0046346	.0046525
O2	.0000001	.0000001	.0000001
O	.0000001	.0000003	.0000001
OH	.0000220	.0000329	.0000182
H	.0000550	.0000740	.0000477
HO	.0000020	.0000032	.0000016
HO2	.0000004	.0000006	.0000003
HM3	.0000000	.0000005	.0000075
CH4	.0000003	.0000002	.0000003

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M12

0.2

TEMP. °K	1800.00	1900.00	2000.00	2100.00	2200.00	2300.00	2400.00
MOLE WT.	24.2259	23.9517	23.8166	23.7450	23.7063	23.6820	23.6673
P	23555	25047	26462	27844	29209	30552	31894
•	- 955.74	- 354.29	- 210.82	- 780.68	- 745.14	- 710.07	- 675.00
CV	33353.	334852	337095	339531	341624	343336	345389
γ	1.27243	1.26957	1.26620	1.26245	1.25893	1.25566	1.25364
γ	2.00512	2.02703	2.04620	2.06257	2.07639	2.08900	2.11042
γ	397.30	437.00	474.17	500.38	544.05	578.28	612.77
γF	1348.25	1342.07	1347.21	1346.32	1245.47	1344.55	1344.08
CO ₂	0.82729	0.87500	0.919044	0.95828	0.994059	0.995205	0.995902
CO	0.04268	0.070374	0.098626	0.127270	0.156187	0.093249	0.094069
H ₂ O	0.099319	0.060647	0.060760	0.060386	0.059318	0.059198	0.058793
H ₂	0.0079256	0.011303	0.012831	0.014068	0.014106	0.014014	0.013573
H	0.0045521	0.0045609	0.0045968	0.0046059	0.0046115	0.0046153	0.0046183
O ₂	0.0000001	0.0000005	0.0000001	0.0000002	0.0000003	0.0000007	0.0000012
N ₂	0.0000001	0.0000006	0.0000006	0.0000012	0.0000021	0.0000035	0.0000056
NO	0.0000001	0.0000005	0.0000001	0.0000002	0.0000003	0.0000007	0.0000012
OH	0.0000001	0.0000005	0.0000001	0.0000002	0.0000003	0.0000007	0.0000012
HO	0.0000001	0.0000005	0.0000001	0.0000002	0.0000003	0.0000007	0.0000012
CO ₂	0.0000001	0.0000005	0.0000001	0.0000002	0.0000003	0.0000007	0.0000012
CO	0.0000001	0.0000005	0.0000001	0.0000002	0.0000003	0.0000007	0.0000012
H ₂ O	0.0000001	0.0000005	0.0000001	0.0000002	0.0000003	0.0000007	0.0000012
H ₂	0.0000001	0.0000005	0.0000001	0.0000002	0.0000003	0.0000007	0.0000012
H	0.0000001	0.0000005	0.0000001	0.0000002	0.0000003	0.0000007	0.0000012
O ₂	0.0000001	0.0000005	0.0000001	0.0000002	0.0000003	0.0000007	0.0000012
N ₂	0.0000001	0.0000005	0.0000001	0.0000002	0.0000003	0.0000007	0.0000012
NO	0.0000001	0.0000005	0.0000001	0.0000002	0.0000003	0.0000007	0.0000012
OH	0.0000001	0.0000005	0.0000001	0.0000002	0.0000003	0.0000007	0.0000012
HO	0.0000001	0.0000005	0.0000001	0.0000002	0.0000003	0.0000007	0.0000012

PROPERTY, THERMODYNAMIC PROPERTIES AND COMPOSITION, GAS COMPOSITION,

2.4

2.

DATE	DESCRIPTION	AMOUNT	CHECK NO.	BANK	DATE	DESCRIPTION	AMOUNT	CHECK NO.	BANK
12-1-57	...	25.00	...	...	12-1-57	...	25.00	...	...
12-2-57	...	25.00	...	...	12-2-57	...	25.00	...	...
12-3-57	...	25.00	...	...	12-3-57	...	25.00	...	...
12-4-57	...	25.00	...	...	12-4-57	...	25.00	...	...
12-5-57	...	25.00	...	...	12-5-57	...	25.00	...	...
12-6-57	...	25.00	...	...	12-6-57	...	25.00	...	...
12-7-57	...	25.00	...	...	12-7-57	...	25.00	...	...
12-8-57	...	25.00	...	...	12-8-57	...	25.00	...	...
12-9-57	...	25.00	...	...	12-9-57	...	25.00	...	...
12-10-57	...	25.00	...	...	12-10-57	...	25.00	...	...
12-11-57	...	25.00	...	...	12-11-57	...	25.00	...	...
12-12-57	...	25.00	...	...	12-12-57	...	25.00	...	...
12-13-57	...	25.00	...	...	12-13-57	...	25.00	...	...
12-14-57	...	25.00	...	...	12-14-57	...	25.00	...	...
12-15-57	...	25.00	...	...	12-15-57	...	25.00	...	...
12-16-57	...	25.00	...	...	12-16-57	...	25.00	...	...
12-17-57	...	25.00	...	...	12-17-57	...	25.00	...	...
12-18-57	...	25.00	...	...	12-18-57	...	25.00	...	...
12-19-57	...	25.00	...	...	12-19-57	...	25.00	...	...
12-20-57	...	25.00	...	...	12-20-57	...	25.00	...	...
12-21-57	...	25.00	...	...	12-21-57	...	25.00	...	...
12-22-57	...	25.00	...	...	12-22-57	...	25.00	...	...
12-23-57	...	25.00	...	...	12-23-57	...	25.00	...	...
12-24-57	...	25.00	...	...	12-24-57	...	25.00	...	...
12-25-57	...	25.00	...	...	12-25-57	...	25.00	...	...
12-26-57	...	25.00	...	...	12-26-57	...	25.00	...	...
12-27-57	...	25.00	...	...	12-27-57	...	25.00	...	...
12-28-57	...	25.00	...	...	12-28-57	...	25.00	...	...
12-29-57	...	25.00	...	...	12-29-57	...	25.00	...	...
12-30-57	...	25.00	...	...	12-30-57	...	25.00	...	...
12-31-57	...	25.00	...	...	12-31-57	...	25.00	...	...

32

6
7
8

103

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M12

0.3

TEMP. °K 2900.00 3000.00 2855.82

MOL. WT.

P 23.6553 23.6574
 C 66355 68631 65360
 - 495.58 - 458.69
 CV 355465 356465 .354933
 T 1.24428 1.24242 1.24522
 S 2.13143 2.14392 2.12584
 E 784.47 820.45 768.82
 HF 1336.33 1335.47 1336.82

CO
 CO2
 H2
 H2O
 N2
 O2
 O
 OH
 H
 NO
 N
 NH3
 CH4

.0202151 .0202624 .0201980
 .0028518 .0028153 .0028672
 .0052521 .0052302 .0052694
 .0092600 .0092938 .0092471
 .0046116 .0046169 .0046127
 .0000001 .0000001
 .0000122 .0000182 .0000101
 .0000266 .0000359 .0000232
 .0000111 .0000017 .0000009
 .0000002 .0000003 .0000002
 .0000382 .0000307 .0000358
 .0000048 .0000037 .0000055

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.4

N12

TEMP. °K	2400.00	2500.00	2600.00	2700.00	2800.00	2900.00	3000.00
P	23.8541	23.7594	23.7601	23.7331	23.7134	23.7057	23.6783
ρ	84016	87524	90982	94437	97872	101271	104719
CV	- 670.61	- 637.00	- 603.16	- 569.96	- 536.43	- 493.81	- 450.64
γ	1.252440	1.253519	1.255037	1.25776	1.261450	1.265081	1.268557
β	1.15738	1.15738	1.15738	1.15738	1.15738	1.15738	1.15738
β	2.03929	2.03929	2.03929	2.03929	2.03929	2.03929	2.03929
β	.85	.85	.85	.85	.85	.85	.85
β	.65	.65	.65	.65	.65	.65	.65

CO	.0201306	.0202769	.0203634	.0204553	.0204923	.0205336	.0205856
CO2	.0027810	.0026354	.0025250	.0024575	.0023952	.0023317	.0022650
H2O	.0049392	.0049301	.0049398	.0049320	.0048709	.0048401	.0048112
H2	.0093214	.0094413	.0094923	.0095336	.0095769	.0096002	.0096340
NO	.0043725	.0045856	.0045573	.0045324	.0045960	.0045932	.0045519
O2	.0000008	.0000015	.0000026	.0000042	.0000067	.0000103	.0000154
NO2	.0000031	.0000049	.0000073	.0000099	.0000149	.0000205	.0000277
H	.0000001	.0000001	.0000002	.0000003	.0000005	.0000009	.0000014
OH	.0000780	.0000652	.0000679	.0000622	.0000587	.0000553	.0000525
C2H2	.0000036	.0000423	.0000294	.0000211	.0000159	.0000116	.0000090

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M12 0.4

TEMP. °K 2851.14

MOL. WT. 23.7080
P 99615
e .358110
CV 1.24871
γ 2.08721
S 765.08
E 1333.08
HF

CO	.0205154
CO2	.0025170
H2	.0048563
H2O	.0095944
N2	.0045954
O2	
OH	.0000024
H	.0000176
NO	.0000007
N	.0000001
NH3	.0000608
CH4	.0000136

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M14

0.05

TEMP. °K	1400.00	1500.00	1600.00	1700.00	1800.00	1900.00	2000.00
WOL. RT.	24.3225	23.8069	23.3614	23.1944	23.1304	23.1034	23.0905
P	3727	4092	4411	4707	4994	5277	5559
e	- 982.58	- 921.88	- 877.09	- 839.29	- 804.02	- 769.58	- 735.41
CV	316745	317875	320277	323152	326060	328759	331341
γ	1.27475	1.27815	1.27720	1.27447	1.27133	1.26833	1.26559
S	2.05473	2.09664	2.12558	2.14850	2.16806	2.18727	2.20480
E	250.00	309.01	351.54	387.20	420.73	453.61	486.43
HF	1266.62	1285.80	1285.83	1231.36	1250.10	1278.56	1277.22
CO ₂	.0169602	.0186000	.0194166	.0198487	.0201168	.0203103	.0204611
CO	.0053876	.007582	.0043846	.0040936	.0038872	.0037192	.0035800
H ₂	.0070002	.0078931	.0081353	.0081095	.0079880	.0078698	.0077435
H ₂ O	.0254314	.0055991	.0061940	.0064274	.0064197	.0067822	.0069191
O ₂	.0044043	.0045074	.0045522	.0045701	.0045776	.0045812	.0045832
CH ₄							
N ₂			.0000001	.0000002	.0000004	.0000008	.0000015
Ar							
OH							
HCN	.0000225	.0000203	.0000171	.0000141	.0000117	.0000099	.0000085
CH ₃	.0007780	.0003227	.0001255	.0000504	.0000218	.0000102	.0000052

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION:

M14 0.05

TEMP. °K	2100.00	2200.00	2300.00	2400.00	2500.00	2600.00	2700.00
WGL. WT.	23.0839	23.0792	23.0749	23.0703	23.0640	23.0569	23.0465
P	5840	6121	6400	6680	6960	7240	7521
e	- 701.23	- 666.93	- 632.53	- 597.98	- 562.91	- 527.62	- 491.95
CV	.333781	.325994	.337990	.339984	.341690	.343306	.344804
γ	1.26292	1.26054	1.25800	1.25564	1.25495	1.25337	1.25201
S	2.22147	2.23742	2.25272	2.26686	2.28174	2.29559	2.30905
E	519.42	552.64	586.02	619.77	653.59	687.74	722.12
MF	1276.03	1274.95	1273.93	1273.13	1271.89	1270.76	1269.47
CO	.0205858	.0206918	.0207840	.0208432	.0209364	.0209998	.0210580
CO2	.0034613	.0033589	.0032696	.0032132	.0031235	.0030639	.0030112
H2	.0076384	.0075403	.0074520	.0073969	.0073072	.0072450	.0071855
H2O	.0070370	.0071389	.0072279	.0072840	.0073731	.0074312	.0074816
H2	.0045844	.0045652	.0045860	.0045806	.0045877	.0045882	.0045892
O2							
OH	.0000003	.0000006	.0000011	.0000021	.0000038	.0000065	.0000106
H	.0000029	.0000050	.0000084	.0000135	.0000208	.0000310	.0000448
NO			.0000001	.0000001	.0000002	.0000004	.0000008
N						.0000001	.0000002
HM3	.0000074	.0000066	.0000060	.0000054	.0000045	.0000046	.0000043
CH4	.0000029	.0000017	.0000010	.0000007	.0000004	.0000003	.0000002

0.05

169

4-1-1

0.1

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PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.1

M14

TEMP. °K	2800.00	2900.00	2721.62
MOL. WT.	23.0530	23.0413	23.0613
P	16671	17271	16201
e	- 457.43	- 421.10	
CV	.347572	.348911	.346428
γ	1.25053	1.24903	1.25181
S	2.25607	2.26882	2.24527
E	754.92	789.83	727.62
HF	1267.75	1266.34	1268.68

CO	.0212183	.0212643	.0211790
CO2	.0028469	.0028073	.0028818
H2	.0070170	.0069730	.0070530
H2O	.0076438	.0076790	.0076111
N2	.0045660	.0045862	.0045852
O2			
C	.0000001	.0000001	
CH	.0000117	.0000180	.0000082
H	.0000434	.0000597	.0000332
NO	.0000009	.0000015	.0000006
N	.0000002	.0000004	.0000001
NH3	.0000092	.0000103	.0000096
CH4	.0000008	.0000006	.0000010

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M14

0.2

TEMP. °K	1700.00	1800.00	1900.00	2000.00	2100.00	2200.00	2300.00
MOL. WT.	24.7025	24.0097	23.6072	23.3890	23.2700	23.2042	23.1628
P	22374	24073	25661	27160	28609	30028	31418
•	- 878.35	- 827.76	- 783.87	- 744.46	- 707.24	- 671.12	- 635.74
CV	332139	333271	334702	336684	338943	340932	342619
7	1.27580	1.27513	1.27321	1.27045	1.26708	1.26383	1.26150
S	1.99510	2.01902	2.04273	2.06294	2.08109	2.09786	2.11362
E	341.65	391.16	435.87	472.25	508.54	543.61	578.39
HF	1274.38	1273.72	1272.80	1271.90	1271.04	1270.23	1269.46
CO	.0185102	.0195215	.0201694	.0205528	.0208150	.0209860	.0211160
CO2	.0040049	.0030691	.0033938	.0032001	.0030668	.0029578	.0028662
H2	.0000134	.0062279	.0065114	.0069503	.0069599	.0069567	.0069245
H2O	.0007548	.0070132	.0072136	.0075443	.0074584	.0075540	.0076376
H2	.0044557	.0044706	.0045111	.0045349	.0045489	.0045574	.0045632
O							
OH							
H	.0000001	.0000002	.0000003	.0000001	.0000001	.0000003	.0000005
N2				.0000007	.0000013	.0000022	.0000038
N							
NH3	.0000591	.0000563	.0000517	.0000463	.0000417	.0000376	.0000341
CH4	.0006737	.0003911	.0002167	.0001236	.0000718	.0000437	.0000267

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M14

0.2

TEMP. °K	2400.00	2500.00	2600.00	2700.00	2800.00	2900.00	2723.62
MOL. WT.	23.1387	23.1179	23.1079	23.0966	23.0860	23.0782	23.0940
P	32801	34173	35540	36907	38274	39636	37230
Q	- 600.54	- 565.05	- 529.61	- 494.07	- 458.17	- 421.99	
CV	344010	340232	347673	348958	350416	351725	349287
Y	1.25829	1.25025	1.25399	1.25217	1.25011	1.24822	1.25175
S	2.12804	2.14311	2.15702	2.17043	2.18349	2.19619	2.17355
L	613.03	647.64	682.29	717.03	752.04	787.14	725.27
MF	1266.92	1268.04	1267.26	1266.47	1265.59	1264.52	1266.27
CO	.0211936	.0212966	.0213609	.0214184	.0214781	.0215102	.0214303
CO2	.0028102	.0027240	.0026665	.0026192	.0025719	.0025395	.0026085
H2	.0069012	.0068418	.0067951	.0067545	.0067139	.0066769	.0067453
H2O	.0016896	.0017736	.0018265	.0018739	.0019158	.0019572	.0019841
O2	.0045670	.0045717	.0045722	.0045742	.0045758	.0045749	.0045746
O							
OH	.0000010	.0000018	.0000031	.0000051	.0000071	.0000124	.0000057
H	.0000061	.0000093	.0000139	.0000202	.0000282	.0000392	.0000221
HO	.0000001	.0000001	.0000002	.0000004	.0000006	.0000010	.0000004
N				.0000001	.0000002	.0000003	.0000001
NO	.0000312	.0000259	.0000267	.0000248	.0000235	.0000263	.0000244
CH4	.0000176	.0000116	.0000081	.0000050	.0000044	.0000032	.0000054

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M14 0.3

TEMP. °K	2000.00	2100.00	2200.00	2300.00	2400.00	2500.00	2600.00
MOL. WT.	23.3046	23.5946	23.4274	23.3104	23.2516	23.1996	23.1753
P	46551	49187	51726	54179	56595	58972	61323
CV	- 755.56	- 714.34	- 675.51	- 638.34	- 601.97	- 565.58	- 529.56
Y	1.27193	1.26889	1.26576	1.26303	1.26066	1.25803	1.25557
S	2.03906	2.02915	2.04718	2.06374	2.07866	2.09410	2.10824
E	650.95	497.32	535.40	571.98	607.91	643.59	678.93
MF	1267.29	1266.72	1266.13	1265.54	1265.15	1264.48	1263.81
CO	.0233425	.0207798	.0210696	.0212304	.0214040	.0215378	.0216167
CO2	.0029698	.0026075	.0026743	.0025676	.0025040	.0024154	.0023603
H2O	.0065401	.0062423	.0063476	.0064008	.0064300	.0064149	.0063918
H2	.0076501	.0077747	.0078730	.0079568	.0080079	.0080382	.0080617
O2	.0044711	.0044999	.0045190	.0045325	.0045414	.0045514	.0045550
N2	.0000005	.0000001	.0000002	.0000004	.0000008	.0000014	.0000025
NO	.0000005	.0000009	.0000016	.0000028	.0000045	.0000069	.0000105
NO2	.0000017	.0000064	.0000077	.00000652	.00000601	.00000503	.00000519
CH4	.0000185	.0000209	.00001291	.00000817	.00000550	.00000367	.00000256

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PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

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PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M14

0.4

TEMP. °K 2719.53

MOL. WT. 23.2468
P 97996
CV 355912
 γ 1.25658
 λ 2.38492
 ϵ 718.23
HF 1259.23

CO .0219590
CO2 .0019626
H2 .0059051
H2O .0085161
N2 .0045301
O2 .0000037
OH .0000124
NO .0000009
NH3 .0010001
CH4 .0000834
.0000440

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M15

0.05

TEMP. °K	1400.00	1500.00	1600.00	1700.00	1800.00	1900.00	2000.00
MOL. WT.	23.1320	22.1911	21.7649	21.6230	21.5551	21.5250	21.5100
P	4308	4392	4734	5053	5362	5667	5970
CV	- 681.76	- 622.05	- 576.42	- 537.40	- 500.91	- 465.27	- 429.90
Y	.327467	.329448	.332374	.335654	.338924	.341972	.344878
S	1.28506	1.28726	1.28560	1.28277	1.27908	1.27617	1.27320
E	2.15371	2.19495	2.22442	2.24809	2.26894	2.28620	2.30635
HF	273.24	325.43	366.53	402.81	437.47	471.71	505.97
	1019.11	1012.38	1008.20	1005.60	1003.82	1002.46	1001.35
CO	.0111399	.0123807	.0130364	.0133925	.0136126	.0137685	.0138872
CO2	.0034576	.0029832	.0026772	.0024634	.0022901	.0021704	.0020634
H2	.0086974	.0097218	.0101114	.0101853	.0101424	.0100652	.0099842
H2O	.0056601	.0062867	.0070770	.0072443	.0073885	.0075119	.0076159
N2	.0124327	.0126965	.0128161	.0128697	.0128923	.0129034	.0129095
O2							
OH							
H							
NO			.0000001	.0000002	.0000004	.0000009	.0000001
N							.0000015
HN3	.0000520	.0000473	.0000401	.0000335	.0000272	.0000241	.0000209
CH4	.0000791	.0000345	.0000143	.0000063	.0000022	.0000013	.0000007

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M15 0.05

TEMP. °K	2100.00	2200.00	2300.00	2400.00	2500.00	2600.00	2700.00
MOL. WT.	21.5014	21.4955	21.4904	21.4851	21.4777	21.4710	21.4636
P	6272	6573	6874	7174	7475	7776	8078
e	- 394.47	- 358.88	- 323.13	- 287.16	- 250.67	- 213.88	- 176.85
CV	.347631	.350123	.352373	.354599	.356554	.358384	.360074
γ	1.27339	1.26785	1.26575	1.26363	1.26179	1.26008	1.25861
S	2.32363	2.34018	2.35607	2.37100	2.38528	2.40071	2.41476
E	540.43	375.13	610.03	645.32	680.72	716.41	752.33
HF	1000.40	999.53	998.85	997.95	996.90	995.81	994.51

CO	.0139835	.0140642	.0141333	.0141776	.0142464	.0142923	.0143344
CO2	.0019723	.0018964	.0018200	.0017583	.0017225	.0016793	.0016413
H2	.0095076	.0092362	.0097761	.0097364	.0096731	.0096267	.0095865
H2O	.0077045	.0077811	.0078473	.0078886	.0079540	.0079958	.0080317
N2	.0129133	.0129160	.0129183	.0129204	.0129237	.0129253	.0129283
O2							
C							
CH	.0000003	.0000005	.0000011	.0000020	.0000036	.0000060	.0000098
H	.0000033	.0000058	.0000097	.0000155	.0000239	.0000357	.0000516
NO			.0000001	.0000002	.0000003	.0000006	.0000011
N					.0000001	.0000002	.0000003
NH3	.00000185	.00000166	.00000151	.00000138	.00000116	.00000105	.00000112
CH4	.0000039	.0000024	.0000015	.0000010	.0000007	.0000005	.0000003

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

W15 0.05

TEMP. °K 2600.00 2538.66

MOL. WT.
P 21.4470 21.4751
8360 7591
e - 138.82
CV .361717 .357276
γ 1.25718 1.26111
S 2.42852 2.39196
E 768.54 694.48
HF .992.91 996.48

CO .0143727 .0142669
CO2 .0016081 .0017031
H2 .0095499 .0095531
H2O .0080614 .0079730
N2 .0129324 .0129245
O2 .0000001 .0000001
OH .0000156 .0000044
H .0000731 .0000281
C .0000019 .0000004
O .0000000 .0000001
NH3 .0000107 .0000114
CH4 .0000003 .0000006

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PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M15 0.1

TEMP. °K	2100.00	2200.00	2300.00	2400.00	2500.00	2600.00	2700.00
MOL. WT.	21.5512	21.5328	21.5201	21.5108	21.5000	21.4945	21.4852
P	13367	14037	14681	15326	15969	16611	17254
e	- 396.45	- 360.44	- 324.49	- 288.38	- 251.84	- 215.13	- 178.10
CV	349451	351886	354032	356266	358193	359964	361577
γ	1.27164	1.26871	1.26640	1.26392	1.26177	1.25977	1.25812
β	2.25247	2.26921	2.28520	2.30019	2.31549	2.32989	2.34388
E	537.41	572.58	607.75	643.25	678.59	714.72	750.74
HF	999.31	998.45	997.71	997.12	996.22	995.34	994.55
CO	.0140517	.0141410	.0142149	.0142610	.0143303	.0143747	.0144153
CO2	.0018718	.0017967	.0017319	.0016916	.0016279	.0015865	.0015499
H2	.0097178	.0096735	.0096283	.0095994	.0095478	.0095058	.0094714
H2O	.0076100	.0075817	.0075445	.0075039	.0074473	.0073871	.0073223
O2	.0123866	.0122942	.0122657	.0122039	.0121297	.0120407	.0119442
O							
OH	.0000002	.0000004	.0000007	.0000014	.0000025	.0000042	.0000068
H	.0000023	.0000040	.0000066	.0000107	.0000165	.0000246	.0000357
N							
NO			.0000001	.0000001	.0000002	.0000004	.0000007
N2					.0000001	.0000001	.0000002
CH4	.0000420	.0000378	.0000344	.0000313	.0000284	.0000273	.0000259
	.0000168	.0000114	.0000070	.0000037	.0000031	.0000032	.0000016

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M15 0.1

TEMP. °K 2800.00 2541.83

MOL. WT.
P 21.4744 21.4970
e 17898 16236
CV - 140.60 .358953
Z .363226 1.26091
S 1.25641 2.32162
E 2.35750 693.85
HF 787.05 995.85
993.17

CO .0144516 .0143519
CO2 .0015180 .0016078
H2 .0094397 .0095290
H2O .0081517 .0080669
O2 .0129177 .0129107
O

OH .0000108 .0000031
H .0000504 .0000196
NO .0000012 .0000003
N .0000004 .0000001
NH3 .0000243 .0000260
CH4 .0000012 .0000027

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M15

0.2

TEMP. °K	1600.00	1700.00	1800.00	1900.00	2000.00	2100.00	2200.00
MOL. WT.	24.1709	23.2046	22.5588	22.1518	21.9123	21.7725	21.6904
P	21912	23846	25680	27406	29039	30614	32150
e	- 640.60	- 561.07	- 529.13	- 483.17	- 441.56	- 402.36	- 364.42
CV	344280	345489	347122	348868	351120	353661	355867
Z	1.28048	1.28077	1.27966	1.27782	1.27519	1.27191	1.26875
S	2.04128	2.07737	2.10704	2.13188	2.15321	2.17234	2.18997
E	308.54	362.26	409.67	452.37	491.81	529.57	566.45
HF	1012.41	1007.38	1003.39	1000.48	998.54	997.19	996.20

CO	.0111920	.0122089	.0130037	.0135294	.0138774	.0140966	.0142433
CO2	.0027730	.0023767	.0020966	.0018984	.0017623	.0016611	.0015827
H2	.0065206	.0075068	.0082313	.0087026	.0089740	.0091153	.0091800
H2O	.0075401	.0077141	.0078303	.0079199	.0079913	.0080562	.0081144
N2	.0121185	.0123685	.0125475	.0126673	.0127422	.0127883	.0128172
O2							
OH							
H							
NO							
N							
CH3	.0001392	.0001415	.0001370	.0001282	.0001172	.0001070	.0000978
CH4	.0011666	.0007782	.0004320	.0002865	.0001708	.0001034	.0000651

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M15

0.2

TEMP. °K	2300.00	2400.00	2500.00	2600.00	2700.00	2800.00	2544.92
MOL. WT.	21.6563	21.6030	21.5717	21.5607	21.5454	21.5322	21.5643
P	32655	35147	36632	38098	39569	41036	37293
e	- 327.28	- 290.37	- 253.21	- 216.17	- 179.00	- 141.44	
CV	.357752	.354955	.361794	.363425	.364871	.366518	.362552
γ	.26041	1.26355	1.26106	1.25872	1.25656	1.25479	1.25999
Σ	2.22020	2.22163	2.23738	2.25152	2.26595	2.27960	2.24403
HF	602.73	635.06	675.46	711.75	748.17	784.86	691.77
	995.35	994.64	994.11	993.37	992.63	991.77	993.77
CO	.0143527	.0144152	.0144991	.0145466	.0145895	.0146256	.0145245
CO2	.0015173	.0014775	.0014170	.0013792	.0013454	.0013164	.0013972
H2	.0092384	.0092246	.0092150	.0091899	.0091740	.0091558	.0092055
H2O	.0081673	.0082007	.0082564	.0082919	.0083236	.0083503	.0082765
H2	.0126375	.0126508	.0126657	.0126866	.0126754	.0126808	.0126693
O2							
O							
OH	.000105	.0000009	.0000017	.0000028	.0000046	.0000073	.0000021
H	.0000004	.0000000	.0000009	.0000013	.0000026	.0000034	.0000131
NO		.0000001	.0000001	.0000003	.0000005	.0000008	.0000002
N2				.0000001	.0000001	.0000003	.0000001
H2O	.0000598	.0000220	.0000094	.0000079	.0000073	.0000060	.0000086
CH4	.0000409	.0000275	.0000180	.0000131	.0000096	.0000073	.0000157

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M15

0.3

TEMP. °K	1900.00	2000.00	2100.00	2200.00	2300.00	2400.00	2500.00
ρ	22.5777	22.5502	22.2266	22.0276	21.8662	21.7975	21.7200
e	46442	49452	52339	55119	57839	60442	63047
CV	- 505.57	- 490.46	- 412.70	- 371.42	- 331.85	- 293.27	- 254.79
γ	.354705	.356487	.358775	.360615	.362167	.364250	.365928
β	1.27014	1.27432	1.27150	1.26867	1.26671	1.26383	1.26130
ε	2.07008	2.09425	2.11508	2.13477	2.15238	2.16842	2.18450
HF	432.17	470.32	517.90	557.05	595.99	633.83	671.55
	999.98	997.39	995.47	994.09	993.01	992.33	991.65

CO	.0130369	.0139669	.0139421	.0141994	.0143904	.0145065	.0146229
CO2	.0017647	.0015917	.0014663	.0013741	.0013002	.0012559	.0011953
H2	.0072358	.0077721	.0081443	.0083867	.0085539	.0086615	.0087332
H2O	.0082537	.0082927	.0083397	.0083795	.0084176	.0084414	.0084909
N2	.0123939	.0125207	.0126112	.0126741	.0127210	.0127529	.0127880
O2							
OH			.0000001	.0000002	.0000004	.0000007	.0000013
NO	.0000003	.0000006	.0000011	.0000019	.0000032	.0000052	.0000081
NO2						.0000001	.0000001
H							
CH4	.0002132	.0002067	.0001973	.0001863	.0001748	.0001630	.0001386
CH3	.0006400	.0004335	.0002890	.0001950	.0001292	.0000896	.0000620

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.3

M15

TEMP. °K	2600.00	2700.00	2800.00	2947.63
MOL. WT.	21.6839	21.6552	21.6306	21.6996
P	65577	68115	70632	64261
e	- 216.91	- 179.15	- 141.15	
CV	367372	368622	370250	366645
7	1.25834	1.25697	1.25466	1.26012
5	2.19939	2.21363	2.22745	2.19173
E	708.55	745.75	783.03	689.30
HF	990.69	990.27	989.57	991.30
CO	.0146882	.0147441	.0147873	.0146602
CO2	.0011594	.0011274	.0011008	.0011752
H2	.0087470	.0087674	.0087747	.0087468
H2O	.0085140	.0085411	.0085634	.0085054
N2	.0127944	.0128087	.0128190	.0127945
O2				
O				
OH	.0000024	.0000036	.0000057	.0000017
H	.0000122	.0000177	.0000251	.0000099
NO	.0000002	.0000003	.0000006	.0000001
N	.0000001	.0000001	.0000002	
NH3	.0001441	.0001354	.0001290	.0001376
CH4	.0000041	.0000035	.0000025	.0000523

0.4

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PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M15

0.4

TEMP. °K	2700.00	2800.00	2553.52
MOL. WT.			
P	21.8607	21.8112	21.9554
e	103729	107591	98013
CV	- 179.87	- 141.00	.371405
γ	.372972	.374532	1.26154
γ	1.25668	1.25627	2.14914
γ	2.17094	2.18498	686.73
γ	742.60	785.80	988.73
γ	957.05	967.03	
CO ₂	.114820	.114886	.114699
CO	.119175	.119391	.119563
H ₂ O	.108217	.108254	.108292
H ₂	.108755	.108776	.108740
CH ₄	.112656	.112714	.112662
CH			
C ₂ H ₄	.000030	.000047	.000014
C ₂ H ₂	.000135	.000195	.000078
C ₂ H	.000003	.000005	.000001
C ₂	.000001	.000002	
H ₂	.102422	.102322	.102240
CH ₄	.100050	.100066	.100131

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M17

0.05

TEMP. °F	1500.00	1600.00	1700.00	1800.00	1900.00	2000.00	2100.00
Wt. %							
C	73.2107 - 4.228 776.65	25.0941 4420 - 741.33	23.0533 4705 - 706.52	23.0368 4987 - 671.72	23.0288 5268 - 636.98	23.0242 5549 - 602.20	23.0209 5829 - 567.25
H	32.752 - 2.7322	32.7474 - 2.7417	33.1103 1.27008	33.4503 1.26628	33.7583 1.25294	34.0493 1.25995	34.3240 1.25716
N	2.1269 - 326.32	2.15086 362.89	2.17226 396.15	2.19219 429.20	2.21093 462.55	2.22877 496.09	2.24582 529.94
O	1173.35	1170.91	1168.90	1167.21	1165.77	1164.53	1163.43
CO	12.0633	10.9439	10.02393	9.194276	8.45820	7.8100	7.26192
CO ₂	1.1720	1.03901	1.0036846	1.0035073	1.0033560	1.0032324	1.0031247
H ₂	1.1104	1.070526	1.066969	1.067432	1.066053	1.064857	1.063813
H ₂ O	1.1734	1.093301	1.0095413	1.0097175	1.0098666	1.0099924	1.0101002
OH	1.11309	1.129727	1.129505	1.129525	1.129963	1.129985	1.130001
H							
Wt. %							
C	73.2245 - 4.2274	25.0823 4420.274	23.0518 4705.104	23.0352 4987.046	23.0280 5268.007	23.0232 5549.014	23.0204 5829.026
H	32.752 - 2.7324	32.7474 - 2.7417	33.1103 1.27008	33.4503 1.26628	33.7583 1.25294	34.0493 1.25995	34.3240 1.25716
N	2.1269 - 326.32	2.15086 362.89	2.17226 396.15	2.19219 429.20	2.21093 462.55	2.22877 496.09	2.24582 529.94
O	1173.35	1170.91	1168.90	1167.21	1165.77	1164.53	1163.43

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.05

M17

TEMP. °K	2200.00	2300.00	2400.00	2500.00	2600.00	2700.00	2800.00
MOL. WT.	23.0180	23.0145	23.0104	23.0039	22.9965	22.9853	22.9701
P	6109	6389	6669	6949	7229	7510	7792
e	- 332.10	- 498.78	- 461.24	- 425.15	- 388.77	- 351.92	- 314.44
CV	345696	347885	350077	351975	353740	355354	356939
7	1.25466	1.25263	1.25055	1.24875	1.24710	1.24572	1.24434
S	2.26217	2.27788	2.29271	2.30774	2.32201	2.33591	2.34955
E	564.08	598.44	633.20	668.07	703.27	738.71	774.46
HF	1162.42	1161.47	1160.69	1159.48	1158.30	1156.91	1155.19

CO	.0109134	.0109937	.0110464	.0111221	.0111886	.0112432	.0112875
CO2	.0030317	.0029505	.0028992	.0028175	.0027633	.0027150	.0026724
H2	.0062901	.0062098	.0061587	.0060777	.0060218	.0059730	.0059301
H2O	.0101934	.0102744	.0103252	.0104057	.0104573	.0105013	.0105370
N2	.0130015	.0130028	.0130042	.0130065	.0130081	.0130110	.0130146
O2						.0000001	.0000001
OH	.0000009	.0000016	.0000033	.0000059	.0000100	.0000259	.0000577
H	.0000046	.0000077	.0000123	.0000190	.0000283	.0000409	.0000577
H2O	.0000001	.0000002	.0000003	.0000006	.0000012	.0000022	.0000037
H				.0000001	.0000002	.0000003	.0000005
H3	.0000094	.0000076	.0000069	.0000057	.0000059	.0000055	.0000052
CH4	.0000004	.0000002	.0000001	.0000001	.0000001	.0000001	.0000001

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M17 0.05

TEMP. °K	2900.00	3000.00	3100.00	3200.00	2960.32
MOL. WT.	22.9503	22.9217	22.8857	22.8386	22.9341
P	8074	8358	8644	8932	8245
e	- 276.20	- 227.01	- 196.70	- 154.99	
CV	.358396	.355712	.360943	.362106	.359208
γ	1.24311	1.24206	1.24117	1.24037	1.24246
S	2.36290	2.37625	2.38946	2.40269	2.37093
H	810.48	946.86	883.33	920.57	832.18
HF	1152.99	1150.20	1146.59	1141.57	1151.38

CO	.0113315	.0113753	.0114181	.0114632	.0113580
CO2	.0026344	.0025994	.0025675	.0025369	.0026129
H2	.0058514	.0058605	.0058339	.0058138	.0058718
H2O	.0105642	.0105858	.0105932	.0105925	.0105773
O2	.0130184	.0130250	.0130331	.0130413	.0130221
N2	.0000002	.0000005	.0000009	.0000017	.0000004
CH	.0000004	.0000008	.0000014	.0000026	.0000006
H	.0000395	.0000386	.0000384	.0000192	.0000503
HO	.0000794	.0001070	.0001414	.0001837	.0000953
NO	.0000062	.0000099	.0000153	.0000230	.0000083
NH3	.0000009	.0000014	.0000022	.0000035	.0000012
CH4	.0000058	.0000047	.0000047	.0000045	.0000054

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M17

O.

TEMP. °K	1600.00	1700.00	1800.00	1900.00	2000.00	2100.00	2200.00
MOL. WT.	23.3118	23.1538	23.0914	23.0621	23.0472	23.0386	23.0327
P	9340	9974	10590	11197	11798	12398	12998
c	- 748.87	- 710.61	- 674.51	- 639.15	- 604.07	- 568.90	- 533.59
CV	.329826	.333072	.336276	.339195	.342068	.344859	.347292
T	1.27916	1.27492	1.27060	1.26672	1.26321	1.25981	1.25680
S	2.08181	2.10500	2.12561	2.14472	2.16272	2.17988	2.19630
E	354.47	390.58	424.98	458.93	492.85	526.98	561.37
HF	1169.32	1167.31	1165.67	1164.29	1163.13	1162.11	1161.19

CO	.0099325	.0102874	.0105184	.0106890	.0108212	.0109308	.0110236
CO2	.0038097	.0035689	.0033839	.0032332	.0031102	.0030056	.0029155
H2	.0066440	.0066297	.0065592	.0064314	.0063299	.0062370	.0061538
H2O	.0094474	.0096649	.0098417	.0099897	.0101121	.0102167	.0103070
N2	.0128989	.0129467	.0129682	.0129791	.0129854	.0129893	.0129921
C2							
O							
OH							
H	.0000001	.0000002	.0000002	.0000005	.0000010	.0000018	.0000032
NO							
N							
NH3	.0000492	.0000405	.0000336	.0000283	.0000242	.0000212	.0000188
CH4	.0001150	.0000475	.0000210	.0000100	.0000051	.0000028	.0000017

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.1

W17

TEMP. °K	2300.00	2400.00	2500.00	2600.00	2700.00	2800.00	2900.00
MOL. WT.	23.0278	23.0231	23.0163	23.0113	23.0027	22.9916	22.9789
P	13594	14192	14788	15385	15982	16580	17178
e	- 422.23	- 422.65	- 420.58	- 390.31	- 353.74	- 316.84	- 279.00
CV	349375	351594	353474	355172	356699	358296	359743
Y	1.25449	1.25198	1.24981	1.24784	1.24625	1.24456	1.24303
S	2.21203	2.22067	2.24190	2.25613	2.26993	2.28342	2.29663
E	555.80	630.77	665.80	701.10	736.58	772.38	808.27
HF	1160.33	1159.67	1158.63	1157.67	1156.58	1155.28	1153.66
CO2	0.000009	0.011555	0.012355	0.012927	0.013423	0.013870	0.014273
H2O	0.028305	0.027867	0.027059	0.026544	0.026075	0.025652	0.025298
CO	0.000742	0.000322	0.000565	0.000928	0.001568	0.002181	0.002779
H2	0.000561	0.004356	0.005151	0.005656	0.006097	0.006464	0.006750
O2	0.000544	0.0129964	0.0129956	0.0130016	0.0130031	0.0130059	0.0130079
N2	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Ar	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
CH4	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
C2H6	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
C3H8	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
C4H10	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
C5H12	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
C6H14	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
C7H16	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
C8H18	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
C9H20	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
C10H22	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
C11H24	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
C12H26	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
C13H28	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
C14H30	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
C15H32	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
C16H34	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
C17H36	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
C18H38	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
C19H40	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
C20H42	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.1

W17

TEMP. °K	3000.00	3100.00	3200.00	2968.74
MOL. WT.	22.9573	22.9325	22.8993	22.9650
P	17780	18382	18989	17591
e	- 240.63	- 201.52	- 161.37	
CV	361074	362221	363401	360536
γ	1.24172	1.24055	1.23950	1.24211
S	2.10964	2.32246	2.33520	2.30560
E	844.73	891.27	918.15	833.33
HF	1151.67	1149.11	1145.87	1152.33

CO	0114675	0115055	0115441	0114551
CO2	0024959	0024659	0024374	0025053
H2	0057495	0057229	0057024	0057573
H2O	0106988	0107123	0107205	0106919
H2	0130138	0130186	0130254	0130115
O2	0000002	0000004	0000008	0000002
O	0000004	0000007	0000012	0000003
H	0004009	0005592	0008335	0000363
H	0007335	0009272	0001262	0000671
NO	0000068	0000125	0000155	0000059
N	0000010	0000016	0000025	0000009
NH3	0000104	0000105	0000096	0000117
CH4	0000001	0000001	0000001	0000001

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

Y17

0.2

TEMP. °K	1900.00	2000.00	2100.00	2200.00	2300.00	2400.00	2500.00
MOL. WT.	23.1975	23.1346	23.1003	23.0802	23.0663	23.0565	23.0444
P	25462	23862	28246	29621	30983	32347	33703
e	- 644.15	- 607.76	- 571.78	- 535.91	- 500.26	- 464.38	- 428.07
CV	.342667	.345416	.348282	.350657	.352524	.354801	.356643
γ	1.27090	1.26598	1.26282	1.25915	1.25658	1.25345	1.25077
S	2.07083	2.08950	2.10706	2.12374	2.13900	2.15457	2.16970
E	450.65	485.96	521.02	555.09	590.99	626.33	661.79
HF	1160.87	1159.86	1158.97	1158.19	1157.45	1156.92	1156.09

CO	.0108748	.0110439	.0111686	.0112008	.0112500	.0114017	.0114823
CO2	.0029640	.0028385	.0027063	.0026504	.0025752	.0025283	.0024520
H2	.0056632	.0059298	.0058772	.0058199	.0057633	.0057282	.0056664
H2O	.0102627	.0103815	.0104612	.0105663	.0106414	.0106883	.0107658
N2	.0129204	.0129427	.0129559	.0129645	.0129707	.0129753	.0129820
O2							
OH		.0000001	.0000002	.0000004	.0000008	.0000016	.0000026
H	.0000003	.0000005	.0000012	.0000021	.0000035	.0000056	.0000086
HO					.0000001	.0000001	.0000003
N							
NH3	.0000097	.0000604	.0000532	.0000474	.0000427	.0000389	.0000322
CH4	.0000525	.0000279	.0000156	.0000094	.0000057	.0000037	.0000025

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.2

M17

TEMP. °K	2600.00	2700.00	2800.00	2900.00	3000.00	3100.00	3200.00
Wt. %							
C	23.0402	23.0318	23.0225	23.0161	22.9964	22.9796	22.9554
H	35055	36409	37763	39111	40471	41826	43188
O	- 391.66	- 352.15	- 318.14	- 280.79	- 242.79	- 204.39	- 165.18
N	358204	359549	361166	362587	363749	364888	366073
Cl	1.24837	1.24656	1.24442	1.24249	1.24087	1.23948	1.23800
Br	2.18558	2.19777	2.21125	2.22435	2.23721	2.24980	2.26224
I	697.39	732.09	769.14	805.28	841.90	878.50	915.47
HF	1155.30	1154.48	1153.53	1152.32	1150.95	1149.17	1146.95
CO	0.116323	0.115796	0.116211	0.116561	0.116945	0.117270	0.117604
CO2	0.024242	0.023604	0.023220	0.022892	0.022569	0.022256	0.022037
H2	0.056183	0.055792	0.055441	0.055069	0.054862	0.054617	0.054441
H2O	0.108114	0.108537	0.108891	0.109157	0.109424	0.109590	0.109709
N2	0.129326	0.129859	0.129659	0.129884	0.129961	0.129993	0.130052
O2					0.000001	0.000002	0.000003
OH				0.000001	0.000002	0.000003	0.000003
H	0.000048	0.000078	0.000124	0.000190	0.000282	0.000408	0.000576
N	0.000128	0.000185	0.000261	0.000360	0.000485	0.000640	0.000832
NO	0.000006	0.000011	0.000017	0.000028	0.000046	0.000071	0.000107
NO2	0.000001	0.000001	0.000003	0.000004	0.000007	0.000011	0.000017
HNO3	0.000001	0.000001	0.000001	0.000001	0.000001	0.000001	0.000001
CH4	0.000001	0.000001	0.000001	0.000001	0.000001	0.000001	0.000001

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.2

M17

TEMP. °K 2973.96

MOL. WT.
P 23.0029
40116

CV .353472
Y 1.24126
S 2.23389
E 832.32
HF 1:51.32

CO	.0116842
CO2	.0022652
H2	.0054900
H2O	.0109355
N2	.0129933
O2	.0000000
OH	.0000001
CH	.0000255
H	.0000449
NO	.0000141
N	.0000006
HF	.0000285
CH4	.0000006

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M17

0.3

TEMP. °K	2300.00	2400.00	2500.00	2600.00	2700.00	2800.00	2900.00
MOL. WT.	23.1343	23.1125	23.0867	23.0827	23.0709	23.0601	23.0580
P	53123	52459	51774	60071	62373	64670	66946
CV	- 501.61	- 465.24	- 428.50	- 391.82	- 355.14	- 317.97	- 280.62
7	.355921	.358254	.360053	.361474	.362630	.364268	.365663
9	1.25886	1.25536	1.25236	1.24969	1.24779	1.24533	1.24310
E	2.09108	2.10626	2.12157	2.13596	2.14981	2.16353	2.17646
MF	586.23	622.16	658.23	694.22	730.24	766.64	802.99
	1151.99	1153.58	1152.92	1152.24	1151.59	1150.83	1149.81
CO	.0116792	.0116677	.0117511	.0117995	.0118452	.0118846	.0119146
CO2	.0022527	.0022374	.0021651	.0021210	.0020803	.0020451	.0020166
H2	.0053718	.0053564	.0053162	.0052765	.0052475	.0052202	.0051845
H2O	.0119267	.0107716	.0110456	.0110873	.0111270	.0111602	.0111825
O2	.0129521	.0127418	.0129546	.0129555	.0129609	.0129652	.0129621
OH	.0000007	.0000012	.0000022	.0000038	.0000062	.0000098	.0000150
H	.0000026	.0000042	.0000064	.0000096	.0000135	.0000195	.0000269
NO	.0000001	.0000001	.0000002	.0000004	.0000008	.0000013	.0000022
N	.0000016	.0000074	.0000618	.0000001	.0000001	.0000002	.0000004
CH4	.00000178	.0000112	.0000078	.0000034	.0000089	.0000057	.0000020
				.0000054	.0000039	.0000029	.0000022

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.3

M17

TEMP. °K	3000.00	3100.00	3200.00	2973.31
MOL. WT.	23.0344	23.0209	22.9990	23.0429
P	69256	71545	73845	62636
e	- 242.55	- 204.34	- 165.38	
CV	.366705	.367769	.368950	.366462
γ	1.24130	1.23973	1.23800	1.24174
S	2.18934	2.20186	2.21421	2.18592
E	840.03	676.81	914.05	830.07
H _F	1148.81	1147.39	1145.69	1149.07
CO	.0119531	.0119819	.0120125	.0119420
CO ₂	.0019856	.0019613	.0019376	.0019941
H ₂	.0051751	.0051535	.0051418	.0051749
H ₂ O	.0112109	.0112266	.0112398	.0112027
N ₂	.0129740	.0129766	.0129834	.0129591
O ₂		.0000001	.0000002	
O	.0000001	.0000002	.0000003	.0000001
H	.0000224	.0000324	.0000458	.0000202
H ₂ O	.0000363	.0000479	.0000623	.0000335
N ₂	.0000035	.0000055	.0000083	.0000031
O	.0000006	.0000009	.0000014	.0000005
H ₂	.0000500	.0000502	.0000457	.0000551
CH ₄	.0000017	.0000013	.0000011	.0000018

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M17

0.4

TEMP. °K	2600.00	2700.00	2800.00	2900.00	3000.00	3100.00	3200.00
MOL. WT.	23.2519	23.2511	23.2502	23.2500	23.0848	23.0725	23.0493
P	83366	94773	98250	101622	105141	108566	112015
Q	- 390.23	- 354.22	- 316.76	- 279.26	- 240.94	- 202.72	- 163.76
CV	370949	365958	367619	368990	369900	370884	372057
T	1.22566	1.25007	1.24795	1.24548	1.24357	1.24187	1.23994
U	2.12823	2.1120	2.12488	2.12807	2.15103	2.16355	2.17590
E	708.37	727.82	764.66	801.25	838.64	875.88	913.47
HF	1154.75	1148.15	1147.59	1146.67	1145.97	1144.81	1143.46
CO	.0114573	.0121124	.0121576	.0121830	.0122242	.0122500	.0122793
CO2	.0024306	.0017832	.0017509	.0017271	.0016968	.0016756	.0016539
H2	.0054323	.0048657	.0048496	.0048158	.0048224	.0048061	.0048020
H2O	.0107700	.0114140	.0114445	.0114611	.0114921	.0115058	.0115197
O2	.0129157	.0129228	.0129255	.0129235	.0129421	.0129446	.0129536
N2	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
OH	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
H	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
NO	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
HO	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
CH4	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.4

M17

TEMP. °K	2969.24
MOL. WT.	23.0984
	154559
CV	369671
Y	1.24409
Z	2.14797
L	827.16
HF	1146.26
CO	0.177098
CO2	0.17068
H2	0.049159
H2O	0.11811
O2	0.099337
N2	0.00000
OH	0.000167
H	0.00000
HO	0.00000
HT	0.00000
HT	0.00000
HT	0.00000
HT	0.00000
HT	0.00000

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.05

M18

TEMP. °K	1400.00	1500.00	1600.00	1700.00	1800.00	1900.00	2000.00
MOL. WT.	24.6969	23.4049	22.8413	22.6178	22.5294	22.4917	22.4742
P	3798	4187	4525	4836	5134	5427	5717
e	- 968.04	- 901.66	- 852.99	- 813.07	- 776.62	- 741.39	- 706.50
CV	322546	323500	325455	328244	331162	333908	336554
γ	1.27463	1.27945	1.27947	1.27719	1.27420	1.27123	1.26845
S	2.08253	2.12819	2.15964	2.18386	2.20459	2.22373	2.24157
E	244.31	308.56	354.75	392.44	427.07	460.75	494.23
HF	1267.30	1265.99	1263.83	1261.79	1259.03	1258.51	1257.20

CO	.0171900	.0190314	.0200020	.0209087	.0208070	.0210117	.0211657
CO2	.0050935	.0044242	.0040046	.0037229	.0035141	.0033472	.0032103
H2	.0075249	.0086208	.0090479	.0091162	.0090490	.0089410	.0088312
H2O	.0034743	.0039661	.0041486	.0043736	.0045602	.0047181	.0048512
N2	.0042062	.0043218	.0043765	.0043998	.0044098	.0044145	.0044171
O2							
OH							
H							
NO			.0000001	.0000002	.0000004	.0000008	.0000001
N							.0000017
HN3	.0000245	.0000231	.0000198	.0000166	.0000139	.0000118	.0000101
CH4	.0009775	.0004386	.0001808	.0000750	.0000332	.0000157	.0000081

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.05

H18

TEMP. °K	2100.00	2200.00	2300.00	2400.00	2500.00	2600.00	2700.00
MOL. WT.	22.4646	22.4589	22.4539	22.4489	22.4422	22.4351	22.4248
P	6056	6295	6583	6871	7158	7447	7735
ρ	- 671.53	- 636.98	- 602.32	- 566.92	- 531.29	- 495.43	- 459.17
CV	.335063	.341346	.343409	.345468	.347536	.348911	.350466
γ	.26577	1.26335	1.26137	1.25937	1.25765	1.25604	1.25465
Σ	2.25553	2.27474	2.29028	2.30464	2.31977	2.33384	2.34752
E	527.52	561.54	595.56	629.58	664.27	698.99	733.95
HF	1256.13	1354.97	1253.97	1253.13	1251.95	1250.82	1249.53
CO	.0212914	.0213932	.0214856	.0215435	.0216342	.0216957	.0217521
CO2	.0032043	.0029546	.0029079	.0029523	.0027566	.0027092	.0026535
H2	.0087284	.0086354	.0085522	.0084936	.0084124	.0083522	.0082983
H2O	.0064650	.0070644	.0071500	.0072048	.0072913	.0073472	.0073959
CH4	.0044185	.0044195	.0044203	.0044213	.0044224	.0044229	.0044239
O2	.0000002	.0000003	.0000010	.0000019	.0000033	.0000061	.0000096
N2	.0000031	.0000054	.0000090	.0000145	.0000223	.0000333	.0000482
NO	.0000009	.0000030	.0000072	.0000166	.0000355	.0000571	.0000853
CH	.0000045	.0000027	.0000016	.0000011	.0000007	.0000005	.0000004

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.05

M18

TEMP. °K	2800.00	2585.63
MOL. WT.	22.4112	22.4362
P	8025	7405
e	-422.37	
c	351572	343375
7	1.25528	1.25526
5	2.36091	2.33188
E	769.20	653.98
HF	1247.99	1250.98

CO	.0218040	.0216897
CO2	.0026141	.0027156
H2	.0082501	.0083592
H2O	.0074370	.0073410
N2	.0044251	.0044229
O2		
J	.0000001	
OH	.0000154	.0000055
H	.0000679	.0000315
HO	.0000011	.0000003
A	.0000003	.0000001
NH3	.0000050	.0000056
CH4	.0000003	.0000005

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M18

0.1

TEMP. °K	1400.00	1500.00	1600.00	1700.00	1800.00	1900.00	2000.00
MOL. WT.	26.9772	24.9566	23.7445	23.0908	22.7712	22.6194	22.5472
P	7736	8642	9472	1023	10914	11571	12207
e	-1021.48	-941.00	-877.12	-826.34	-793.87	-745.61	-709.33
CV	329716	329129	329642	331264	333471	335798	338269
Y	1.26755	1.27495	1.27828	1.27832	1.27633	1.27359	1.27061
S	1.96181	2.03734	2.07862	2.10943	2.13370	2.15438	2.17299
E	185.44	250.37	328.72	377.53	418.22	454.97	489.95
HF	1260.50	162.77	261.29	325.85	375.27	425.86	475.65
CO	.0179177	.0173591	.0169357	.0203625	.0206504	.0209983	.0212175
CO2	.0055724	.0047101	.0041066	.0037032	.0034318	.0032393	.0030895
H2	.0053384	.0066157	.0078163	.0083653	.0085339	.0086267	.0085940
H2O	.0033699	.0059007	.0062549	.0055057	.0066982	.0068559	.0069353
N2	.0040186	.0041773	.0042835	.0043456	.0043782	.0043945	.0044036
O2							
OH							
H				.0000001	.0000003	.0000006	.0000001
HO							.0000011
N							
NH3	.0000352	.0000383	.0000374	.0000341	.0000299	.0000260	.0000227
CH4	.0017561	.0010705	.0005806	.0002906	.0001424	.0000711	.0000377

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M18

0.1

TEMP. °K	2100.00	2200.00	2300.00	2400.00	2500.00	2600.00	2700.00
MOLE WT.	22.5104	22.4901	22.4769	22.4679	22.4586	22.4522	22.4434
P	12835	13459	14076	14694	15309	15925	16541
e	- 673.78	- 635.46	- 603.30	- 568.07	- 532.40	- 496.61	- 460.55
CV	340736	342958	344925	346987	348732	350351	351838
γ	1.26754	1.26475	1.26250	1.26015	1.25810	1.25620	1.25460
z	2.19032	2.20674	2.22238	2.23680	2.25195	2.26599	2.27960
E	524.45	533.75	543.03	552.32	562.19	572.03	582.00
HF	1254.56	1253.61	1252.70	1252.03	1250.97	1250.03	1249.01

CO	.0213729	.0214919	.0215901	.0216514	.0217432	.0218037	.0218587
CO2	.0029705	.0026709	.0027849	.0027311	.0026460	.0025900	.0025405
H2	.0085327	.0084636	.0083956	.0083514	.0082744	.0082188	.0081701
H2O	.0070959	.0071913	.0072749	.0073274	.0074117	.0074663	.0075143
N2	.0044085	.0044115	.0044137	.0044153	.0044174	.0044177	.0044189
O2							
OH	.0000002	.0000004	.0000007	.0000014	.0000024	.0000042	.0000066
H	.0000021	.0000037	.0000062	.0000099	.0000153	.0000228	.0000331
HO				.0000001	.0000001	.0000002	.0000004
N						.0000001	.0000001
NH3	.0000201	.0000180	.0000163	.0000149	.0000124	.0000128	.0000119
CH4	.0000212	.0000127	.0000077	.0000051	.0000034	.0000023	.0000017

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.1

M18

TEMP. °K	2900.00	2588.85
MOL. WT.	22.4329	22.4528
P	17158	15856
•	- 424.06	
CV	.353349	.350177
7	1.25295	1.25641
S	2.29287	2.26448
E	767.37	693.13
MF	1247.83	1250.13
CO	.0219750	.0217534
CO2	.0024972	.0025943
H2	.0081258	.0082245
H2O	.0075552	.0074617
N2	.0044201	.0044178
O2		
OH	.0000108	.0000039
•	.0000467	.0000219
NO	.0000008	.0000002
•	.0000002	.0000001
•	.0000113	.0000126
CH4	.0000013	.0000024

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M18

0.2

TEMP. °K	1600.00	1700.00	1800.00	1900.00	2000.00	2100.00	2200.00
MOL. WT.	25.7326	24.4947	23.6835	23.1815	22.9730	22.7288	22.6355
P	20910	22828	24633	26323	27910	29433	30914
•	- 925.95	- 862.20	- 807.78	- 760.60	- 718.70	- 679.70	- 642.30
CV	.338304	.338517	.339415	.340625	.342470	.344670	.346635
γ	1.27311	1.27522	1.27536	1.27417	1.27190	1.26883	1.26576
S	1.57752	2.01620	2.04730	2.07279	2.09428	2.11329	2.13066
E	274.42	337.38	390.51	436.35	477.11	515.13	551.67
HF	1254.69	1254.66	1253.88	1252.86	1251.92	1251.04	1250.24
CO	.0170650	.0167043	.0193555	.0205276	.0211059	.0214185	.0216224
CO2	.0043513	.0037752	.0033565	.0030525	.0028625	.0027165	.0026050
H2	.0055340	.0054675	.0071525	.0075853	.0078252	.0079334	.0079674
H2O	.0063748	.0057320	.0069774	.0071556	.0072863	.0073925	.0074819
H2	.0041011	.0042030	.0042756	.0043239	.0043539	.0043721	.0043834
O							
OH							
H	.0000001	.0000001	.0000002	.0000004	.0000001	.0000001	.0000002
NO					.0000007	.0000014	.0000024
N							
H3	.0000632	.0000656	.0000643	.0000604	.0000552	.0000503	.0000458
CH4	.0013413	.0008773	.0005409	.0003192	.0001378	.0001122	.0000696

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

H28

C.2

TEMP. °K	2300.00	2400.00	2500.00	2600.00	2700.00	2800.00	2591.34
MOL. WT.	22.5762	22.5418	22.5135	22.4997	22.4855	22.4732	22.5003
P	32359	33791	35210	36621	38032	39440	36499
•	- 605.90	- 569.68	- 533.64	- 497.52	- 461.33	- 424.79	
CV	348342	350360	352018	353502	354836	356342	353381
7	1.26353	1.26078	1.25836	1.25611	1.25428	1.25222	1.25630
S	2.14687	2.15162	2.15701	2.16119	2.16485	2.16813	2.19001
E	587.28	622.75	656.13	693.47	728.87	764.53	690.41
HF	1249.49	1248.96	1248.12	1247.35	1246.57	1245.70	1247.41

CO	.0217729	.0218619	.0219706	.0220376	.0220964	.0221463	.0220335
CO2	.0025129	.0024569	.0023731	.0023193	.0022720	.0022311	.0023228
H2	.0079674	.0079631	.0079199	.0078818	.0078484	.0078155	.0078849
H2O	.0075605	.0076093	.0076890	.0077388	.0077836	.0078220	.0077355
N2	.0043912	.0043963	.0044022	.0044030	.0044054	.0044073	.0044091
O2							
O							
OH	.0000005	.0000009	.0000017	.0000028	.0000047	.0000074	.0000027
H	.0000040	.0000065	.0000100	.0000150	.0000218	.0000307	.0000145
NO			.0000001	.0000002	.0000003	.0000005	.0000002
N					.0000001	.0000001	.0000001
NH3	.0000418	.0000384	.0000320	.0000331	.0000309	.0000293	.0000327
CH4	.0000432	.0000288	.0000191	.0000133	.0000096	.0000073	.0000137

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.3

M18

TEMP. °K	2000.00	2100.00	2200.00	2300.00	2400.00	2500.00	2600.00
MOL. WT.	23.5223	23.1797	22.9547	22.7992	22.7061	22.6326	22.5555
P	47698	50300	53187	55772	58300	60783	63224
Q	- 733.83	- 689.94	- 648.98	- 610.05	- 572.37	- 534.86	- 497.52
CV	347671	349513	351061	352412	354290	355783	357078
Z	1.27207	1.26954	1.26682	1.26497	1.26220	1.25971	1.25733
S	2.03711	2.05850	2.07752	2.09485	2.11032	2.12623	2.14374
E	457.85	500.91	541.12	579.25	616.59	653.42	689.67
HF	1247.57	1246.76	1246.16	1245.57	1245.19	1244.56	1243.90
CO	.020688	.0212202	.0215809	.0218458	.0220037	.0221605	.0222532
CO2	.0026817	.0024867	.0023448	.0022324	.0021654	.0020769	.0020222
H2	.0066928	.0070143	.0072116	.0073374	.0074135	.0074374	.0074367
H2O	.0074025	.0077158	.0078046	.0078802	.0079267	.0079511	.0079650
N2	.0042739	.0043038	.0043328	.0043504	.0043622	.0043752	.0043776
O2							
OH							
H	.0000005	.0000001	.0000002	.0000004	.0000007	.0000013	.0000023
N		.0000010	.0000017	.0000030	.0000048	.0000074	.0000111
NO						.0000001	.0000001
H3	.0000553	.0000511	.0000487	.0000461	.0000445	.0000428	.0000412
CH4	.0004554	.0003033	.0002019	.0001315	.0000902	.0000612	.0000432

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.3

M18

TEMP. °K	2700.00	2800.00	2992.43
MOL. WT.	22.5538	22.5409	22.5971
P	65638	68077	63041
Q	- 461.20	- 424.26	
CV	358230	359710	356987
X	1.25544	1.25311	1.25750
Y	2.15460	2.16804	2.13959
Z	725.77	762.02	686.95
HF	1263.29	1242.61	1243.95
CO	.0223292	.0223880	.0222483
CO2	.0019750	.0019355	.0020252
H2	.0074333	.0074214	.0074376
H2O	.0030860	.0031208	.0080428
N2	.0043327	.0043864	.0043777
O2			
OH	.0000037	.0000059	.0000022
H	.000162	.0000229	.0000105
NO	.0000002	.0000004	.0000001
N	.0000001	.0000001	
CH3	.0000010	.0000059	.0000645
CH4	.0000015	.0000020	.0000442

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M18

0.4

TEMP. °K	2000.00	2100.00	2200.00	2300.00	2400.00	2500.00	2600.00
MOL. WT.	24.3026	23.8479	23.4808	23.1987	23.0154	22.8650	22.7817
P	72340	76477	80757	84880	88875	92783	96566
Q	- 752.54	- 704.03	- 659.32	- 617.12	- 576.97	- 537.41	- 499.02
CV	353433	355097	356241	357242	358901	360145	361176
γ	1.27316	1.27095	1.26867	1.26737	1.26482	1.26252	1.26021
Δ	1.98757	2.01136	2.03212	2.05091	2.06743	2.08418	2.09927
Δ	434.92	492.28	526.39	568.02	607.83	646.91	684.67
HF	1242.12	1241.80	1241.44	1241.05	1240.82	1240.44	1239.87
CO	.200872	.0207975	.0213199	.0217326	.0219966	.0222386	.0223854
CO2	.0025449	.0022996	.0021195	.0019759	.0018882	.0017867	.0017255
H2	.0054105	.0058636	.0062041	.0064735	.0066599	.0067861	.0068503
H2O	.0070990	.0090342	.0081323	.0082108	.0082565	.0083287	.0083660
H2	.0041780	.0042234	.0042582	.0042865	.0043069	.0043299	.0043352
O2							
O							
OH	.0000001	.0000001	.0000002	.0000003	.0000006	.0000011	.0000019
H	.0000007	.0000007	.0000013	.0000022	.0000036	.0000057	.0000085
NO						.0000001	.0000001
N							
NH3	.0001386	.0001390	.0001363	.0001320	.0001259	.0001085	.0001138
CH4	.0007879	.0005743	.0004164	.0002918	.0002108	.0001495	.0001091

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.4

M18

TEMP. °K 2700.00 2800.00 2595.23

MO. WT. 22.7142 22.6678 22.7843
 P 100323 104030 96388
 - 461.27 - 423.54
 CV 362118 363534 361132
 7 1.25840 1.25594 1.26032
 S 2.11352 2.12724 2.09858
 H 721.94 759.13 682.90
 HF 1235.43 1238.52 1239.50

CO 0.223504 0.223841 0.223803
 CO2 0.0016743 0.0016337 0.0017275
 H2 0.0068994 0.0069249 0.0068465
 H2O 0.0024028 0.0024336 0.0023650
 O2 0.0043449 0.0043517 0.0043352

OH 0.000031 0.000049 0.000013
 H 0.0000125 0.0000177 0.0000084
 N2 0.0000002 0.0000003 0.0000001
 HCN 0.0000001 0.0000001 0.0000001
 NH3 0.0000004 0.0000005 0.0000002
 CH4 0.0000002 0.0000002 0.0000001

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION.

M26

0.2

TEMP. °K	2700.00	2800.00	2900.00	3000.00	3100.00	3200.00	3300.00
MOL. WT.	23.8097	23.8006	23.7927	23.7758	23.7594	23.7369	23.7099
P	35542	36861	38178	39501	40824	42150	43481
•	- 590.70	- 554.56	- 518.10	- 481.11	- 443.74	- 405.69	- 366.93
CV	351183	352669	353984	355087	356157	357260	358211
γ	1.24475	1.24265	1.24075	1.23911	1.23769	1.23622	1.23451
γ	2.15014	2.14325	2.13606	2.12861	2.20085	2.21292	2.22487
E	718.48	753.67	788.99	824.71	860.49	896.62	932.58
MF	1366.52	1365.58	1364.44	1363.19	1361.61	1359.70	1357.33

CO	0187182	0187702	0188153	0188623	0189035	0189454	0189865
CO2	0035113	0034640	0034229	0033841	0033507	0033195	0032910
H2	0055178	0052727	0052292	0051966	0051642	0051372	0051135
H2O	0093883	0094331	0094693	0095031	0095275	0095474	0095593
H2	0050168	0050201	0050195	0050226	0050235	0050253	0050268
O2				0000001	0000001	0000003	0000003
N	0000062	0000109	0000001	0000001	0000003	0000005	0000009
N	0000080	0000253	0000168	0000250	0000352	0000513	0000711
N	0000005	0000010	0000016	0000048	0000118	0000212	0000324
N	0000001	0000002	0000003	0000026	0000041	0000061	0000080
N	0000078	0000168	0000187	0000204	0000207	0000211	0000216
CH4	0000020	0000015	0000011	0000150	0000151	0000137	0000131
			0000011	0000009	0000007	0000005	0000004

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[illegible]

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

1MR

0.05

TEMP. °K	1500.00	1600.00	1700.00	1800.00	1900.00	2000.00	2100.00
MOL. WT.	24.1524	23.8632	23.7636	23.7266	23.7110	23.7035	23.6991
P	4001	4298	4581	4857	5132	5405	5678
e	- 997.05	- 956.26	- 920.06	- 885.34	- 851.05	- 816.88	- 782.63
CV	.317765	.320625	.323723	.326734	.329485	.332102	.334570
γ	1.27354	1.27126	1.26797	1.26461	1.26154	1.25875	1.25613
S	2.07614	2.10249	2.12444	2.14428	2.15281	2.16034	2.16705
E	314.88	353.65	387.78	420.63	453.27	486.00	518.97
HF	136	1366.16	1364.15	1362.30	1360.66	1359.23	1357.96
CO	.0170710	.0176987	.0180566	.0183021	.0184921	.0186462	.0187765
CO2	.0055291	.0051620	.0048945	.0046823	.0045058	.0043579	.0042310
H2	.0072054	.0072258	.0070944	.0069329	.0067775	.0066391	.0065167
H2O	.0068064	.0071240	.0075748	.0075812	.0077556	.0079028	.0080295
O2	.0045822	.0046116	.0046227	.0046274	.0046297	.0046310	.0046318
O							
OH							
H		.0000001	.0000001	.0000003	.0000001	.0000001	.0000003
HO					.0000007	.0000014	.0000027
N							
NH3	.0000176	.0000143	.0000115	.0000094	.0000079	.0000067	.0000059
CH4	.0001917	.0000589	.0000265	.0000112	.0000052	.0000026	.0000014

505

219

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.05

1MR

TEMP. °K	2900.00	3000.00	2867.22
MOL. WT.	23.6302	23.6037	23.6369
P	7863	8139	7773
c	- 499.40	- 461.61	
CV	.348411	.349638	.347984
Z	1.24285	1.24182	1.24322
S	2.31108	2.32389	2.30685
E	791.79	827.18	780.27
HF	1347.59	1345.21	1348.27
CO	.0193915	.0194449	.0193742
CO2	.0036509	.0036104	.0036649
H2	.0059285	.005869	.0059437
H2O	.0085909	.0085202	.0085797
N2	.0046380	.0045399	.0046377
O2	.0000002	.0000003	.0000001
O	.0000003	.0000006	.0000002
OH	.0000320	.0000475	.0000280
H	.0000795	.0001070	.0000718
NO	.0000030	.0000042	.0000025
N	.0000005	.0000008	.0000004
NH3	.0000035	.0000028	.0000033
CH4	.0000001	.0000001	.0000001

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

1MR

C.1

TEMP. °K	1500.00	1600.00	1700.00	1800.00	1900.00	2000.00	2100.00
MOL. WT.	25.1341	24.3309	23.9755	23.8274	23.7635	23.7342	23.7192
P	8347	9067	9720	10336	10936	11526	12114
e	-1021.70	-968.93	-926.54	-889.06	-853.51	-818.76	-784.18
CV	.321498	.323512	.325864	.328514	.331046	.333593	.336077
γ	1.27412	1.27438	1.27201	1.26864	1.26521	1.26196	1.25873
S	1.99762	2.03172	2.05743	2.07885	2.09806	2.11589	2.13273
E	285.79	338.09	379.09	415.02	449.08	482.52	515.92
HF	1362.93	1362.97	1361.81	1360.35	1358.91	1357.62	1356.46
CO	.0160972	.0173016	.0179611	.0183376	.0185828	.0187580	.0188965
CO2	.0056546	.0051455	.0048022	.0045593	.0043713	.0042218	.0040960
H2	.0061070	.0065882	.0067141	.0066717	.0065710	.0064611	.0063549
H2O	.0068204	.0072149	.0074988	.0077171	.0078950	.0080405	.0081648
N2	.0044842	.0045597	.0045956	.0046119	.0046198	.0046239	.0046263
O2							
OH							
H			.0000001	.0000002	.0000005	.0000010	.0000020
NO							
N							
NH3	.0000326	.0000291	.0000247	.0000207	.0000175	.0000149	.0000130
CH4	.0005807	.0002611	.0001125	.0000500	.0000236	.0000120	.0000066

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

INR 0.1

TEMP. °K	2200.00	2300.00	2400.00	2500.00	2600.00	2700.00	2800.00
MOL. WT.	23.7105	23.7042	23.6990	23.6925	23.6871	23.6789	23.6683
P	12700	13282	13865	14446	15027	15610	16193
Q	- 745.58	- 715.02	- 680.33	- 645.17	- 609.87	- 574.30	- 538.25
CV	338276	340088	342212	343905	345464	346884	348341
7	1.25591	1.25372	1.25137	1.24934	1.24747	1.24592	1.24425
S	2.14884	2.16422	2.17847	2.19335	2.20720	2.22062	2.23372
E	549.45	323.04	617.00	651.01	685.31	719.81	754.67
MF	1355.40	1354.41	1353.69	1352.54	1351.55	1350.48	1349.26

CO	.0190113	.0191103	.0191730	.0192718	.0193377	.0193979	.0194524
CO2	.0035822	.0038938	.0038344	.0037393	.0036763	.0036203	.0035711
H2	.0062573	.0061683	.0061124	.0060602	.0060103	.0059600	.0059100
H2O	.0062716	.0063656	.0064246	.0065193	.0065802	.0066348	.0066897
O2	.0046279	.0046251	.0046300	.0046314	.0046317	.0046326	.0046336
N2	.0000000	.0000000	.0000015	.0000033	.0000056	.0000092	.0000146
NO	.0000032	.0000053	.0000085	.0000131	.0000195	.0000281	.0000396
OH	.0000000	.0000001	.0000001	.0000002	.0000004	.0000007	.0000012
HF	.0000000	.0000000	.0000000	.0000000	.0000001	.0000001	.0000002
CH4	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.1

1MA

TEMP. °K	2900.00	3000.00	2873.24
MDL. WT.	23.6556	23.6361	23.6592
P	16776	17363	16620
C _V	- 511.61	- 464.72	- 349330
Y	349674	350864	1.24319
S	1.24281	1.24151	2.24312
E	2.24652	2.25909	780.22
HF	789.60	824.95	1348.22
	1347.80	1340.37	
CO	0195121	0195513	0194893
CO2	0035276	0034880	0035387
H2O	0058034	0057648	0058155
H2	0037185	0037507	0037552
O2	0046339	0046359	0046339
N2	0000001	0000001	0000001
NO	0000001	0000001	0000001
CH4	0000224	0000333	0000201
HCN	0000545	0000733	0000502
NO2	0000021	0000033	0000018
CO	0000004	0000006	0000003
CH	0000078	0000063	0000075
OH	0000003	0000002	0000003

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

IMR

0.2

TEMP. °K	1800.00	1900.00	2000.00	2100.00	2200.00	2300.00	2400.00
WCL. WT.	24.2662	24.0042	23.8735	23.8057	23.7690	23.7460	23.7320
P	23502	24975	26381	27758	29117	30455	31793
Q	- 901.11	- 860.66	- 823.30	- 787.33	- 751.85	- 716.62	- 681.73
CV	.332237	.334669	.336930	.339377	.341475	.343187	.345237
7	1.27221	1.26920	1.26578	1.26201	1.25854	1.25609	1.25318
5	2.50270	2.50245	2.50369	2.506125	2.50774	2.50934	2.510774
E	198.21	437.71	474.05	509.15	543.76	577.94	612.40
HF	1355.51	1354.53	1353.66	1352.77	1351.92	1351.09	1350.52

CO	.0181044	.0186414	.0189313	.0191255	.0192664	.0193758	.0194483
CO2	.0043525	.0041045	.0039311	.0037968	.0036878	.0035939	.0035359
H2	.0058793	.0059776	.0059802	.0059376	.0058778	.0058137	.0057722
H2O	.0079877	.0081931	.0083458	.0084699	.0085740	.0086632	.0087219
N2	.0045565	.0045842	.0045995	.0046082	.0046135	.0046172	.0046197
O2							
OH							
H	.0000001	.0000003	.0000006	.0000012	.0000021	.0000035	.0000050
HO							.0000001
H3	.0000476	.0000420	.0000367	.0000324	.0000289	.0000260	.0000235
CH4	.0002245	.0001165	.0000623	.0000349	.0000208	.0000125	.0000082

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

1MR

0.2

TEMP. °K	2500.00	2600.00	2700.00	2800.00	2900.00	3000.00	2876.53
MOL. WT.	23.7186	23.7121	23.7033	23.6941	23.6863	23.6695	23.6880
P	33119	34445	35772	37099	38422	39753	38112
e	- 646.35	- 610.90	- 575.34	- 539.37	- 502.09	- 466.30	- 352.073
CV	346366	348325	349593	351051	352354	353463	352073
7	1.25065	1.24835	1.24655	1.24447	1.24257	1.24094	1.24300
5	2.12274	2.13665	2.15008	2.16316	2.17589	2.18835	2.17293
E	646.87	681.49	716.21	751.25	786.41	821.97	778.14
HF	1349.57	1348.74	1347.91	1346.98	1345.86	1344.65	1346.14
CO	.0195502	.0196147	.0196733	.0197250	.0197698	.0198164	.0197599
CO2	.00334439	.0033842	.0033309	.0032843	.0032438	.0032058	.0032528
H2	.0056947	.0056384	.0055895	.0055454	.0055023	.0054704	.0055123
H2O	.0028133	.0028713	.0029231	.0029673	.0029933	.0030068	.0029956
H2	.0046230	.0046234	.0046248	.0046250	.0046255	.0046285	.0046258
O2						.0000001	.0000001
O					.0000001	.0000001	.0000001
OH	.0000023	.0000039	.0000064	.0000101	.0000155	.0000231	.0000141
H	.0000055	.0000127	.0000184	.0000259	.0000356	.0000460	.0000331
N2	.0000001	.0000003	.0000005	.0000008	.0000014	.0000022	.0000012
N			.0000001	.0000002	.0000003	.0000004	.0000002
NO			.0000001	.0000002	.0000003	.0000004	.0000002
CH4	.0000053	.0000036	.0000025	.0000020	.0000014	.0000011	.0000016

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

IMR

0.3

TEMP. °K	2200.00	2300.00	2400.00	2500.00	2600.00	2700.00	2800.00
MOL. WT.	23.8518	23.8302	23.7949	23.7548	23.7519	23.7378	23.7261
P	50180	52503	54814	57093	59360	61627	63890
e	- 754.51	- 718.28	- 682.55	- 646.58	- 610.77	- 575.00	- 538.84
CV	345051	346516	348567	350150	351453	352555	354030
7	1.26146	1.25904	1.25579	1.25296	1.25040	1.24845	1.24604
8	2.02941	2.04546	2.06016	2.07539	2.08945	2.10295	2.11610
E	537.11	572.45	607.77	642.97	678.07	713.16	748.56
HF	1347.66	1347.04	1346.62	1345.87	1345.17	1344.49	1343.74
CO	.0194533	.0196479	.0197384	.0198529	.0199213	.0199823	.0200340
CO2	.0033603	.0032599	.0031992	.0031080	.0030508	.0029998	.0029557
H2	.0053839	.0053654	.0053510	.00532981	.0052545	.0052170	.0051810
H2O	.0089106	.0090030	.0090594	.0091488	.0092029	.0092522	.0092939
O2	.0045689	.0045974	.0046030	.0046098	.0046105	.0046131	.0046151
OH	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
H	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
N2	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
CH4	.0000542	.0000492	.0000448	.0000371	.0000380	.0000352	.0000332
	.0000618	.0000378	.0000249	.0000162	.0000112	.0000080	.0000060

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.3

1.1R

TEMP. °K 2500.00 3000.00 2874.82

MOLE WT.

2 23.7159 23.7033 23.7209
 66.140 68.438 65574
 - 502.48 - 465.61
 355300 356294 355000
 1.24354 1.24153 1.24437
 2.12257 2.14135 2.12569
 -92.92 819.52 775.06
 1342.60 1341.85 1343.05

CO
 CO2
 H2
 H2O
 O2
 OH
 H
 NO
 NH3
 CH4

200757 2001222 200661
 2029197 2028820 2029274
 2051431 2051205 2051531
 2093261 2093600 2093189
 2046136 2046187 2046143
 2000124 2000001 2000112
 2000264 2000365 2000244
 2000011 2000018 2000010
 2000002 2000003 2000002
 2000370 2000297 2000355
 2000044 2000034 2000048

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

1MR

0.4

TEMP. °K	2400.00	2500.00	2600.00	2700.00	2800.00	2900.00	3000.00
MOL. WT.	23.9084	23.8471	23.8197	23.7941	23.7753	23.7680	23.7413
P	83752	87241	90685	94126	97549	100937	104369
e	- 683.25	- 646.38	- 609.57	- 573.82	- 537.31	- 500.71	- 463.57
CV	.352243	.353720	.354866	.355785	.357261	.358491	.359367
7	1.25497	1.25699	1.25427	1.25226	1.24958	1.24713	1.24511
S	2.02131	2.03691	2.05121	2.06486	2.07814	2.09100	2.10356
E	602.63	638.95	674.75	710.37	746.28	782.04	818.51
HF	1347.10	1341.59	1341.01	1340.49	1339.90	1339.07	1338.42
CO	.0220025	.0201475	.0202300	.0203004	.0203566	.0203977	.0204452
CO2	.0028462	.0027508	.0026935	.0026431	.0026008	.0025671	.0025305
H2	.0045446	.0048301	.0048072	.0047872	.0047647	.0047332	.0047235
H2O	.0094175	.0095080	.0095551	.0096066	.0096462	.0096738	.0097086
H2	.0045766	.0045388	.0045406	.0045953	.0045937	.0045960	.0046044
O2							
O							
CH	.0000008	.0000015	.0000026	.0000043	.0000068	.0000105	.0000001
H	.0000031	.0000048	.0000072	.0000105	.0000148	.0000203	.0000157
N		.0000001	.0000002	.0000003	.0000006	.0000009	.0000015
NH3				.0000001	.0000001	.0000002	.0000003
CH4	.0000756	.0000630	.0000647	.0000601	.0000566	.0000530	.0000507
	.0000590	.0000591	.0000571	.0000519	.000046	.0000407	.0000353

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.4

1st R

TEMP. °K	2870.04
MOL. WT. P	23.7650 99526
CV	.358149
Y	1.24784
Σ	2.08719
E	772.034
IF	1339.34
CO	.0203570
CO2	.0025762
H2O	.0047435
H2	.0096668
O2	.0045575
O	
OH	.0000093
H	.0000195
HO	.0000008
H2O2	.0000002
CH3	.0000050
CH4	.0000118

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

720

0.2

TEMP. °K	2000.00	2100.00	2200.00	2300.00	2400.00	2500.00	2600.00
MOL. WT.	21.5289	21.3361	21.2195	21.1413	21.0934	21.0508	21.0345
P	29820	31483	33094	34665	36216	37756	39272
Q	- 384.92	- 343.74	- 304.41	- 266.17	- 228.43	- 190.58	- 152.94
CV	.355758	.358186	.360321	.362217	.364402	.366253	.367923
Z	1.27657	1.27372	1.27085	1.26866	1.26593	1.26353	1.26122
Y	2.17969	2.19978	2.21806	2.23507	2.25075	2.26658	2.28196
E	445.91	535.39	573.06	610.24	647.28	684.35	721.20
MF	946.67	944.84	943.57	942.59	941.94	941.18	940.42
CO	.0140216	.0142891	.0144654	.0145936	.0146700	.0147546	.0148033
CO2	.0014770	.0013788	.0013044	.0012438	.0012071	.0011532	.0011197
H2	.0095679	.0102426	.0103646	.0104690	.0105196	.0105420	.0105323
H2O	.0074595	.0074985	.0075381	.0075766	.0076011	.0076486	.0076752
H2	.0130977	.0131623	.0132037	.0132327	.0132521	.0132735	.0132769
O2							
OH		.0000001	.0000002	.0000004	.0000008	.0000014	.0000024
H	.0000008	.0000015	.0000028	.0000047	.0000075	.0000116	.0000174
HO				.0000001	.0000001	.0000001	.0000002
N							.0000001
HM3	.0001421	.0001316	.0001215	.0001123	.0001038	.0000877	.0000910
CH4	.0002625	.0001642	.0001058	.0000676	.0000459	.0000313	.0000222

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.2

T20

TEMP. °K 2324.69

MOL. WT. 21.1267
33050

CV 362730
1.26823
2.23907
619.40
942.40

CO2 0146172
CO 0012325
H2O 0106847
H2 0075839
O2 0122254

0000005
0000053

0001102
0001607

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

T25

0.2

TEMP. °K	2700.00	2500.00	2900.00	3000.00	3100.00	3200.00	3300.00
MOL. WT.	24.0255	24.0176	24.0096	23.9928	23.9762	23.9534	23.9259
O	35201	36508	37813	39124	40434	41749	43057
e	- 520.59	- 573.71	- 534.39	- 457.57	- 455.34	- 422.43	- 383.81
CV	345657	351130	352430	353523	354580	355670	356609
7	1.24378	1.24169	1.23980	1.23816	1.23675	1.23527	1.23398
S	2.13890	2.15199	2.16473	2.17721	2.18940	2.20143	2.21330
E	715.37	750.40	785.57	821.14	856.77	892.74	928.96
HF	1379.05	1378.10	1376.97	1375.72	1374.13	1372.21	1369.82

CO	0185341	0165861	0186315	0166785	0187101	0187623	0188043
CO2	0036956	0036481	0036068	0035678	0035341	0035025	0034735
H2	0050215	0049763	0049327	0048995	0048670	0048398	0048160
H2O	0093642	0094340	0094703	0095041	0095288	0095483	0095605
H2	0045369	0045360	0045376	0045404	0045412	0045429	0045445
O2				0000001	0000002	0000003	0000005
OH	0000071	0000113	0000173	0000257	0000303	0000305	0000309
H	0000174	0000246	0000337	0000454	0000500	0000529	0000572
NO	0000006	0000010	0000017	0000027	0000042	0000078	0000094
N	0000001	0000002	0000003	0000004	0000007	0000064	0000095
CH3	0000162	0000152	0000170	0000136	0000136	0000111	0000116
CH4	0000017	0000013	0000009	0000007	0000006	0000024	0000034

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.2

125

TEMP. °K 3090.28

MOL. WT.
P 23.9778
40307

CV 354479
7 1.23687
S 2.18623
E 853.30
HF 1374.30

CO	.0157163
CO2	.0035371
H2	.0048751
H2O	.0095269
N2	.0049412
O2	.0000001
U	.0000003
OH	.0000361
H	.0000584
NO	.0000041
N	.0000007
NH3	.0000135
CH4	.0000006

20

000	0131299	0132144	0132536	0133354	0133794
001	0036030	0035650	0035230	0034716	0034717
002	0040456	0040162	0039863	0039478	0039341
003	0039450	0039746	0039946	0110151	0110154
004	0055108	0055233	0055233	0055297	0055332
005	0030001	0030012	0030033	0030010	0030016
006	0030001	0030002	0030003	0030013	0030022
007	0030222	0030356	0030478	0030937	0031270
008	0030397	0030413	0030546	0030964	0031139
009	0030332	0030354	0030383	0030186	0030267
010	0030302	0030336	0030310	0030322	0030332
011	0030373	0030336	0030339	0030322	0030332
012	0030302	0030302	0030302	0030301	0030301
013	0030302	0030302	0030302	0030301	0030301
014	0030302	0030302	0030302	0030301	0030301
015	0030302	0030302	0030302	0030301	0030301
016	0030302	0030302	0030302	0030301	0030301
017	0030302	0030302	0030302	0030301	0030301
018	0030302	0030302	0030302	0030301	0030301
019	0030302	0030302	0030302	0030301	0030301
020	0030302	0030302	0030302	0030301	0030301
021	0030302	0030302	0030302	0030301	0030301
022	0030302	0030302	0030302	0030301	0030301
023	0030302	0030302	0030302	0030301	0030301
024	0030302	0030302	0030302	0030301	0030301
025	0030302	0030302	0030302	0030301	0030301
026	0030302	0030302	0030302	0030301	0030301
027	0030302	0030302	0030302	0030301	0030301
028	0030302	0030302	0030302	0030301	0030301
029	0030302	0030302	0030302	0030301	0030301
030	0030302	0030302	0030302	0030301	0030301
031	0030302	0030302	0030302	0030301	0030301
032	0030302	0030302	0030302	0030301	0030301
033	0030302	0030302	0030302	0030301	0030301
034	0030302	0030302	0030302	0030301	0030301
035	0030302	0030302	0030302	0030301	0030301
036	0030302	0030302	0030302	0030301	0030301
037	0030302	0030302	0030302	0030301	0030301
038	0030302	0030302	0030302	0030301	0030301
039	0030302	0030302	0030302	0030301	0030301
040	0030302	0030302	0030302	0030301	0030301
041	0030302	0030302	0030302	0030301	0030301
042	0030302	0030302	0030302	0030301	0030301
043	0030302	0030302	0030302	0030301	0030301
044	0030302	0030302	0030302	0030301	0030301
045	0030302	0030302	0030302	0030301	0030301
046	0030302	0030302	0030302	0030301	0030301
047	0030302	0030302	0030302	0030301	0030301
048	0030302	0030302	0030302	0030301	0030301
049	0030302	0030302	0030302	0030301	0030301
050	0030302	0030302	0030302	0030301	0030301
051	0030302	0030302	0030302	0030301	0030301
052	0030302	0030302	0030302	0030301	0030301
053	0030302	0030302	0030302	0030301	0030301
054	0030302	0030302	0030302	0030301	0030301
055	0030302	0030302	0030302	0030301	0030301
<					

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

3.2

729

TEMP. °K 3215.49

MOL. WT. 24.1150
P 0.1356

CV 335494
γ 1.25102
S 2.28749
F 904.71
HF 1511.71

CO₂ 0.333333
CO 0.333333
H₂O 0.333333
H₂ 0.095238
O₂ 0.000000
O 0.000000
H 0.000000
F 0.000000
HF 0.000000
NO 0.000000
N₂ 0.000000
N 0.000000
H₂ 0.000000

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

731

0.2

TEMP. °K	3200.00	3300.00	3400.00	3500.00	3600.00	3700.00	3800.00
MOL. WT.	26.2280	26.1838	26.1267	26.0537	25.9622	25.8487	25.7112
P	37857	39072	40294	41528	42776	44042	45330
C	- 641.71	- 601.85	- 560.68	- 517.98	- 473.26	- 426.41	- 376.84
CV	354627	355514	356270	357110	357984	358751	359410
7	1.21788	1.21665	1.21564	1.21479	1.21390	1.21316	1.21261
5	2.11555	2.12620	2.13848	2.15085	2.16343	2.17629	2.18947
E	867.21	723.80	563.76	998.10	1036.06	1074.45	1113.70
HF	1537.69	1584.43	1580.28	1574.97	1568.27	1559.89	1549.67

CO	.0126416	.0120990	.0129537	.0130249	.0131103	.0132154	.0133374
CO2	.0047695	.0044535	.0041148	.003707	.0032195	.002570	.001870
H2	.0021535	.0021374	.0021264	.0021209	.0021215	.0021273	.0021440
H2O	.0111126	.0111147	.0111090	.0110947	.0110705	.0110373	.0109892
N2	.0059652	.0053603	.0053601	.0053597	.0053587	.0053573	.0053553
O2	.000021	.000037	.000063	.0000104	.0000165	.0000254	.0000377
OH	.000014	.000025	.000042	.000069	.000109	.000168	.000252
H	.0000425	.0001261	.0001738	.0002312	.0003021	.0003882	.0004904
H2O	.0000516	.0000661	.0000832	.0001035	.0001274	.0001552	.0001877
N	.0000177	.0000261	.0000375	.0000526	.0000722	.0000971	.0001277
N2	.000001	.0000016	.0000024	.0000034	.0000048	.0000067	.0000090
H2O	.0000037	.0000035	.0000035	.0000033	.0000031	.0000031	.0000030

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

111 0.2

TEMP. °K	3900.00	3688.37
MOL. WT.	25.5466	25.8631
P	46639	43894
e	- 125.25	
CV	.358662	
7	1.21324	
8	2.17472	
9	1069.96	
HF	1537.26	1560.96
CO	.134337	.0132021
CO2	.0061034	.0062649
H2	.0021692	.0021263
H2O	.005286	.0053417
H2	.005352	.0053575
O2	.000543	.0005242
O3	.0005368	.0005163
OH	.0006103	.0003773
CH	.0002253	.0001512
HCN	.0001647	.0000939
NO	.000121	.0000664
NO2	.000033	.0000331

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

732

0.2

TEMP. °K	2700.00	2800.00	2900.00	3000.00	3100.00	3200.00	3300.00
MOL. WT.	23.5556	23.5667	23.5682	23.5510	23.5350	23.5130	23.4862
P	35930	37264	38597	39934	41269	42609	43952
e	- 617.95	- 579.67	- 486.36	- 449.41	- 412.06	- 374.07	- 335.43
CV	349500	351077	353575	354983	356059	357167	358123
γ	1.24850	1.24669	1.24271	1.24108	1.23963	1.23817	1.23687
z	2.14171	2.13531	2.18431	2.19583	2.20906	2.22111	2.23303
z	0.01115	0.06017	0.0940	0.25.12	0.60.98	0.896.98	0.933.31
MF	1335.64	1331.01	1332.95	1331.73	1330.17	1328.30	1325.66

CO	0.51335	0.51920	0.52889	0.53353	0.53755	0.54105	0.54500
CO ₂	0.032869	0.032331	0.031462	0.030104	0.028773	0.027478	0.026203
H ₂	0.057465	0.056580	0.0550133	0.0535823	0.052509	0.0513239	0.050003
H ₂ O	0.090239	0.089754	0.0891583	0.0881896	0.0872130	0.0862324	0.0852449
H ₂	0.051452	0.051469	0.051462	0.051517	0.051526	0.051547	0.051561
O ₂				0.000001	0.000001	0.000002	0.000003
N ₂	0.000033	0.000033	0.000033	0.000033	0.000033	0.000033	0.000033
H	0.000026	0.000026	0.000026	0.000026	0.000026	0.000026	0.000026
OH	0.000003	0.000003	0.000003	0.000003	0.000003	0.000003	0.000003
H ₂ O	0.0000225	0.0000209	0.0000213	0.0000204	0.0000197	0.0000195	0.0000193
CH ₄	0.000040	0.0000293	0.0000103	0.0000170	0.0000171	0.0000155	0.0000139

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.2

T32

TEMP. °K 3087.43

MOL. WT.
P 23.5369
41101

CV 355926
Y 1.23982
S 2.20754
E 856.39
HF 1330.39

CO .0193709
CO2 .0030817
H2 .0055544
H2O .0052104
N2 .0051526
O2 .0000001
O .0000002
OH .0000323
H .0000619
NO .0000035
N .0000007
NH3 .0000168
CH4 .0000009

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

T33

O.2

TEMP. °K	2700.00	2800.00	2900.00	3000.00	3100.00	3200.00	3300.00
MOL. WT.	23.7178	23.7087	23.7010	23.6839	23.6677	23.6455	23.6190
P	35709	37034	38356	39685	41012	42344	43680
e	- 568.68	- 332.63	- 496.26	- 459.37	- 422.10	- 384.17	- 345.55
CV	.350371	.351850	.353161	.354263	.355332	.356433	.357384
γ	1.24596	1.24388	1.24193	1.24035	1.23893	1.23745	1.23615
S	2.15213	2.16524	2.17801	2.19050	2.20271	2.21474	2.22662
E	717.36	752.47	787.70	823.35	859.04	895.07	931.33
HF	1343.15	1342.22	1341.09	1339.86	1338.30	1336.41	1334.07

CO	.0189452	.0189967	.0190411	.0190876	.0191282	.0191693	.0192099
CO2	.0033489	.0033023	.0032620	.0032238	.0031911	.0031606	.0031327
H2	.0054378	.0054457	.0054036	.0053689	.0053369	.0053103	.0052866
H2O	.0091443	.0091883	.0092240	.0092574	.0092818	.0093013	.0093136
N	.0051893	.0051906	.0051901	.0051934	.0051943	.0051963	.0051979
O2				.0000001	.0000001	.0000002	.0000004
O			.0000001	.0000001	.0000003	.0000005	.0000008
OH	.0000066	.0000105	.0000161	.0000239	.0000347	.0000491	.0000681
H	.0000162	.0000257	.0000353	.0000475	.0000626	.0000815	.0001041
HO	.0000005	.0000009	.0000015	.0000025	.0000039	.0000058	.0000086
N2	.0000001	.0000002	.0000003	.0000004	.0000007	.0000011	.0000016
NH3	.0000190	.0000183	.0000222	.00003161	.0000461	.0000617	.0000812
CH4	.0000023	.0000017	.0000013	.0000015	.0000015	.0000015	.0000015

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

T33 0.2

TEMP. °K 3.35.17

MOL. WT. 25.6606
P 41460

CV 3557.5
Y 1.23841
S 2.20696
E 871.67
HF 1337.67

CO .0191426
CO2 .5031801
H2 .0053269
H2O .0092832
N2 .0051949
O2 .0000002
O .0000003
OH .0000394
T .0000690
NO .0000045
H .0000008
NH3 .0000158
CH4 .0000007

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

T34

0.2

TEMP. °K	2000.00	2100.00	2200.00	2300.00	2400.00	2500.00	2600.00
MOL. WT.	22.0481	21.9344	21.8683	21.8249	21.7979	21.7716	21.7627
P	28720	30257	31763	33242	34712	36174	37622
e	- 478.22	- 439.68	- 402.15	- 365.28	- 328.51	- 291.44	- 254.43
CV	.350996	.353633	.355899	.357794	.360032	.361886	.363513
γ	1.27339	1.27037	1.26706	1.26465	1.26172	1.25917	1.25681
S	2.14065	2.16547	2.18292	2.19932	2.21460	2.23010	2.24463
E	492.21	529.48	566.07	602.14	638.36	674.67	710.93
HF	1035.92	1034.75	1033.87	1033.11	1032.58	1031.85	1031.10

CO	.0135221	.0137191	.0138529	.0139548	.0140162	.0140966	.0141443
CO2	.0019374	.0018351	.0017544	.0016864	.0016448	.0015806	.0015402
H2	.0000231	.0000137	.0000453	.0000502	.0000521	.0000288	.0000571
H2O	.0005295	.0005002	.0004719	.0004315	.0003708	.0003319	.0003089
N2	.0126028	.0126405	.0126641	.0126805	.0126916	.0127053	.0127067
O	.0000001	.0000001	.0000003	.0000006	.0000010	.0000018	.0000031
OH	.0000005	.0000014	.0000025	.0000042	.0000068	.0000106	.0000138
H	.0001069	.0000970	.0000882	.0000806	.0000740	.0000621	.0000501
CH4	.0001317	.0000784	.0000488	.0000305	.0000204	.0000137	.0000096

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

Y34 Q.2

TEMP. °K	2700.00	2800.00	2570.73
MOL. WT.	21.7493	21.7372	21.7635
P	39074	40522	37200
•	- 217.29	- 179.74	
CV	.364545	.366557	.363060
7	1.25497	1.25286	1.25748
5	2.25565	2.27231	2.24048
E	747.31	783.98	700.32
HF	1030.36	1029.49	1031.32
CO	.0141879	.0142250	.0141337
CO2	.0015041	.0014729	.0015495
H2	.0085750	.0085523	.0086072
H2O	.0089033	.0089324	.0088637
H2	.0127126	.0127173	.0127075
O2			
O			
OH	.0000051	.0000061	.0000027
H	.0000229	.0000323	.0000141
H2O	.0000005	.0000009	.0000002
H	.0000001	.0000003	.0000001
H2	.0000000	.0000000	.0000001
CH4	.0000070	.0000054	.0000106

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.2

TEMP. °K	2000.00	2100.00	2200.00	2300.00	2400.00	2500.00	2600.00
LOG. WT.	22.9256	22.7064	22.5771	22.4933	22.4449	22.4260	22.4202
P	28098	29669	31160	32662	34116	35555	36932
Q	- 650.98	- 641.18	- 573.49	- 537.00	- 531.29	- 465.44	- 429.83
CV	337476	336418	341163	342810	344091	346262	347732
Y	1.27493	1.27237	1.26963	1.26750	1.26592	1.26274	1.26150
Z	2.05523	2.05402	2.05213	2.05034	2.04875	2.04632	2.04521
E	52.00	537.25	543.98	579.57	614.79	649.82	684.71
HF	13.56	1172.47	1171.61	1170.53	1170.29	1169.50	1169.77

CO	222422	221601	222955	2230793	2231813	2232935	2233529
CO2	224337	222890	2221801	2220921	2220391	2219531	2219110
H2	2280675	2282053	2283614	2284006	2284299	2284412	2284500
H2O	2262583	2261425	2262119	2262794	2263196	2263375	2264297
O2	2244344	2244382	2244731	2244835	2244902	2244975	2244985
O	2244344	2244382	2244731	2244835	2244902	2244975	2244985
N	2244344	2244382	2244731	2244835	2244902	2244975	2244985
N2	2244344	2244382	2244731	2244835	2244902	2244975	2244985
CH4	2244344	2244382	2244731	2244835	2244902	2244975	2244985

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.2

41 O-O

2510.32

TEMP. °K

22.4031
35703

MOL. WT.
P

.345417
1.26251
2.16972
653.42
1169.42

CV
7
3
E
MF

.0279026
.0015568
.0084100
.0063920
.0046979

CO
CO2
H2
H2O
H2

.0000014
.0000108
.0000001

CH
H
H2O

.0000355
.0000285

N
NH3
CH4

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

MI 2-0

G.2

TEMP. °K	2000.00	2100.00	2200.00	2300.00	2400.00	2500.00	2600.00
MOLE WT.	22.5558	22.2620	22.0864	21.9626	21.8831	21.8434	21.8171
O	22217	32433	32054	32630	35146	36643	38127
CV	- 920.75	- 376.50	- 336.96	- 531.03	- 464.19	- 427.40	- 393.57
7	343575	345173	346847	348465	350322	351899	353367
5	1.27558	1.27352	1.27112	1.26932	1.26692	1.26475	1.26282
HF	2.11403	2.13453	2.15299	2.16980	2.18493	2.20059	2.21489
	471.57	512.34	550.74	587.70	623.94	659.50	695.57
	1147.01	1145.70	1144.69	1143.81	1143.22	1142.43	1141.68
CO	.0226712	.0231235	.0234242	.0236385	.0237652	.0238919	.0239685
CO2	.0021487	.0019959	.0018642	.0017957	.0017427	.0016792	.0016243
H2	.0588948	.0392162	.0094011	.0095128	.0095769	.0095932	.0095907
H2O	.0058530	.0059179	.0059739	.0060251	.0060569	.0061153	.0061316
H2	.043190	.0043491	.0043667	.0043826	.0043916	.0044011	.0044030
OH							
H	.0000005	.0000001	.0000002	.0000004	.0000007	.0000012	.0000020
H2O		.0000015	.0000026	.0000044	.0000071	.0000110	.0000165
H						.0000031	.0000031
H2	.0000685	.0000645	.0000601	.0000559	.0000518	.0000437	.0000454
CH4	.0003863	.0002478	.0001617	.0001040	.0000709	.0000481	.0000340

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

VI 2-0

202

TEMP. °K	2362.44
MW. RT.	41.9199
	34560
CV	349699
Y	1.26785
S	2.17047
E	610.41
LE	1143.41

0.237275
0.017559
0.095537
0.160472
0.043385

0.010005
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PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

MI 4-O

TEMP. °K	2000.00	2100.00	2200.00	2300.00	2400.00	2500.00	2600.00
MOL. WT.							
P	22.2590	21.9008	21.6731	21.5157	21.4208	21.3491	21.3000
e	28476	31240	32927	34551	36132	37691	39133
CV	- 593.16	- 543.24	- 506.77	- 467.19	- 429.05	- 391.21	- 357.43
γ	.349268	.350926	.352471	.354066	.355675	.357437	.359481
γ	1.27566	1.27415	1.27219	1.27062	1.26844	1.26642	1.26432
γ	2.14449	2.16334	2.18165	2.19927	2.21435	2.22698	2.23713
E	473.63	513.59	550.76	586.20	620.58	653.04	683.62
HF	1122.16	1120.53	1119.27	1118.23	1117.54	1116.71	1116.72
CO	.0229549	.0234792	.0238400	.0241344	.0242930	.0244100	.0245040
CO2	.0019133	.0017561	.0016440	.0015546	.0014812	.0014193	.0013640
H2	.0056266	.0100494	.0133710	.0155649	.0168623	.0174923	.0180110
H2O	.0050575	.0056748	.0063710	.0070644	.0076552	.0081433	.0085310
O2	.0042044	.0042406	.0042651	.0042829	.0042947	.0043066	.0043140
OH	.0000001	.0000001	.0000002	.0000003	.0000006	.0000012	.0000014
H	.0000008	.0000015	.0000027	.0000046	.0000075	.0000119	.0000164
N2	.0000775	.0000741	.0000699	.0000656	.0000612	.0000570	.0000539
CH4	.0000302	.0000352	.0000370	.0000386	.0000399	.0000412	.0000426

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

MI 4-0 0.2

TEMP. °K 2233.71

MOL. WT. 21.6129

P 33421

CV 353004

γ 1.27152

ϵ 2.19777

Σ 569.95

HF 1118.90

CO .0239396

CO2 .0016113

H2 .0104453

H2O .0057218

N2 .0042718

O2 .0000000

NO .0000000

NO2 .0000000

HCl .0000000

HBr .0000000

HF .0000000

CH4 .0000000

C2H4 .0000000

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

NI 6-0

C-2

TEMP. °K	2000.00	2100.00	2200.00	2300.00	2400.00	2500.00	2600.00
ρ	22.0340	21.6096	21.3284	21.1271	21.0027	20.9074	20.8323
ρ	31.80	31.940	33716	35423	37075	38699	40287
CV	- 597.99	- 520.59	- 476.62	- 435.41	- 395.86	- 356.83	- 319.37
γ	.355170	.350671	.346090	.341533	.336999	.332486	.327993
ε	1.27532	1.27429	1.27279	1.27131	1.26989	1.26850	1.26713
HF	2.16499	2.16810	2.20842	2.22688	2.24304	2.25764	2.27173
	475.11	520.11	582.08	652.10	730.70	818.73	916.10
	1055.11	1055.97	1095.41	1092.10	1073.24	1042.31	1000.10
CO	.0231323	.0237379	.0241009	.0244802	.0248790	.0252927	.0257241
CO ₂	.0017249	.0015636	.0014473	.0013507	.0012828	.0012338	.0011993
H ₂	.0102056	.0118588	.0132606	.0143994	.0152733	.0159788	.0165389
H ₂ O	.0341741	.0364231	.0384337	.0401453	.0415957	.0428143	.0438289
N ₂	.0044422	.0044431	.0044437	.0044438	.0044438	.0044438	.0044438
O ₂							
H							
OH	.0000009	.0000001	.0000001	.0000003	.0000003	.0000002	.0000001
NO			.0000028	.0000040	.0000079	.0000122	.0000169
H ₂ O	.0000856	.0000831	.0000794	.0000753	.0000717	.0000684	.0000653
CH ₄	.0000937	.0000934	.0000930	.0000929	.0000929	.0000929	.0000929

PROPERTIES AND COMPOSITION

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REV. OF 2126.53

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PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

MI C-2

0.2

TEMP. °K	2000.00	2100.00	2200.00	2300.00	2400.00	2500.00	2600.00
MOLE WT.							
P	22.7692	22.5677	22.4514	22.3765	22.3331	22.2982	22.2809
ρ	28256	29772	31287	32761	34217	35659	37099
ρ	- 684.34	- 644.44	- 606.36	- 569.80	- 533.61	- 497.29	- 461.14
CV	342319	344393	346272	347953	349924	351555	353038
γ	1.27340	1.27062	1.26775	1.26562	1.26297	1.26062	1.25840
S	2.12005	2.11952	2.13715	2.15351	2.16831	2.18376	2.19795
E	475.21	514.01	551.04	586.98	622.62	658.11	693.49
W	1215.14	1214.18	1213.55	1212.59	1212.06	1211.25	1210.49
CO	.0216921	.0220429	.0222723	.0224328	.0225368	.0226491	.0227176
CO2	.0026073	.0024592	.0023480	.0022573	.0022025	.0021225	.0020714
H2	.0021866	.0023557	.0024306	.0024599	.0024752	.0024458	.0024167
H2O	.0037819	.00369765	.00369570	.00370282	.00370725	.00371451	.00371919
H2	.0043517	.0043735	.0043872	.0043966	.0044027	.0044096	.0044137
CH							
CH	.0000001	.0000001	.0000002	.0000004	.0000008	.0000015	.0000020
H	.0000007	.0000014	.0000025	.0000042	.0000067	.0000104	.0000155
N							
N							
OH							
CH3	.0000550	.0000548	.0000503	.0000462	.0000425	.0000356	.0000365
CH4	.0002410	.0001470	.0000926	.0000580	.0000389	.0000260	.0000182

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.2

MI 0-2

TEMP. °K 2428.80

MOL. WT. 22.3221
P 34634

CV 350429
Y 1.26226
S 2.17270
E 632.85
HF 1211.85

CO 3225677
CO2 3021821
H2O 3084655
N2 3070906
O2 3044546

OH 3000013
H 3000076

NO 3000408
CH 3000345

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

MI 0-4

0.2

TEMP. °K	2000.00	2100.00	2200.00	2300.00	2400.00	2500.00	2600.00
MOL. WT.	22.6201	22.4365	22.3310	22.2634	22.2242	22.1923	22.1767
P	28310	29871	31385	32859	34318	35763	37197
e	- 716.22	- 676.19	- 637.96	- 600.89	- 564.28	- 527.48	- 490.24
CV	.347001	.349209	.351186	.352917	.354473	.355867	.357184
γ	1.27197	1.26901	1.26601	1.26382	1.26108	1.25867	1.25641
S	2.11432	2.13383	2.15158	2.16809	2.18309	2.19871	2.21310
E	481.42	520.44	557.75	594.08	630.14	666.38	701.94
HF	1254.75	1253.87	1253.07	1252.32	1251.79	1250.96	1250.10
CO	.0211193	.0214539	.0216739	.0218350	.0219299	.0220425	.0221715
CO2	.0027001	.0026109	.0024976	.0024046	.0023482	.0022646	.0022112
H2	.0082902	.0084345	.0084917	.0085077	.0085129	.0084775	.0084464
H2O	.0074857	.0075900	.0076772	.0077540	.0078017	.0078302	.0078491
N2	.0042716	.0042917	.0043042	.0043129	.0043186	.0043252	.0043260
O2							
OH	.0000001	.0000001	.0000002	.0000005	.0000009	.0000016	.0000029
HO	.0000007	.0000014	.0000025	.0000042	.0000067	.0000104	.0000153
N						.0000001	.0000002
NH3	.0000601	.0000550	.0000503	.0000461	.0000423	.0000384	.0000366
CH4	.0002196	.0001327	.0000831	.0000518	.0000347	.0000231	.0000162

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.2

M1 O-4

2352.43

TEMP. °K

22.2394
33626

MOL. WT.
P

.353955
1.26245
2.17614
613.02
1257.02

CV
T
S
E
H

.0218928
.0023705
.0085117
.0077826
.0043163

CO
CO2
H2
H2O
H2
O2

.0000007
.0000054

OH
H

.0000440
.0000411

N2
CH4

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

W1 C-6

0.2

TEMP. °A	2000.00	2100.00	2200.00	2300.00	2400.00	2500.00	2600.00
W1	22.4837	22.3153	22.2152	22.1579	22.1222	22.0929	22.0787
P	284.03	299.60	314.73	329.48	344.10	358.57	372.96
Q	- 747.01	- 706.85	- 668.36	- 630.93	- 593.90	- 556.65	- 519.52
CV	.351503	.353842	.355911	.357688	.359826	.361577	.363129
Y	1.27003	1.26750	1.26436	1.26214	1.25932	1.25685	1.25456
Z	2.12760	2.11439	2.10526	2.10193	2.10113	2.12192	2.22749
E	487.33	526.37	564.21	600.35	637.33	673.72	710.03
IF	.292.96	1292.14	1291.37	1290.63	1290.10	1289.25	1288.46
CO	.205659	.0206857	.0210974	.0212539	.0213464	.0214393	.0215258
CO2	.002910	.0027457	.0026348	.0025397	.0024518	.0023951	.0023356
H2	.0083734	.0084954	.0085368	.0085411	.0085394	.0084970	.0084585
H2O	.0081759	.0082896	.0083826	.0084643	.0085149	.0085977	.0086492
O2	.0041964	.0042150	.0042266	.0042346	.0042399	.0042461	.0042469
O	.0000001	.0000001	.0000003	.0000005	.0000010	.0000018	.0000031
N	.0000007	.0000014	.0000025	.0000042	.0000067	.0000104	.0000156
N2	.0000003	.0000003	.0000002	.0000001	.0000001	.0000001	.0000002
H	.0000003	.0000003	.0000002	.0000001	.0000001	.0000001	.0000001
CH4	.0000003	.0000003	.0000002	.0000001	.0000001	.0000001	.0000001
CH3	.0000003	.0000003	.0000002	.0000001	.0000001	.0000001	.0000001

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.2

Wt. 0-6

TEMP. °K 2280.47

MOL. WT. 32.62

CV 357363
7 25251
3 217876
5 91.77
HF 1195.77

0.0212274
0.0025568
0.0085431
0.0064492
0.0042333

0.0000005
0.0000003

0.0000066
0.0000509

TEMP. °K

MOL. WT.

CV
7
3
5
HF

CO2
CO
H2O
H2
O2
N2
NH3
CH4

PELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.2

M1 3-3

TEMP. °A	2000.00	2100.00	2200.00	2300.00	2400.00	2500.00	2600.00
MO. WT.	22.1450	21.8615	21.6387	21.5734	21.5054	21.4526	21.4612
P	29314	31012	32642	34217	35761	37286	38768
Q	- 634.24	- 610.87	- 570.27	- 531.35	- 492.44	- 455.60	- 474.04
C _v	.352900	.354857	.356651	.358347	.360036	.362013	.362044
Y	1.27393	1.27174	1.26926	1.26740	1.26492	1.26268	1.26261
Z	2.14870	2.14583	2.14269	2.13902	2.13540	2.13761	2.23389
E	482.54	524.54	564.07	602.05	638.37	676.37	657.94
MF	1194.12	1192.95	1192.00	1191.17	1190.60	1189.80	1189.80
CO ₂	.0221172	.0224745	.0227762	.0229920	.0231210	.0232512	.0232400
CO	.0222544	.0221977	.0219825	.0218976	.0218555	.0217551	.0217603
H ₂ O	.0547711	.0597557	.0709874	.0730997	.0731639	.0731785	.0731648
NO	.0067443	.0066602	.0069270	.0069642	.0070194	.0070350	.0070832
NO ₂	.0041927	.0041831	.0042022	.0042153	.0042242	.0042343	.0042325
N ₂	.0000013	.0000001	.0000002	.0000004	.0000008	.0000013	.0000013
O ₂	.0000013	.0000015	.0000027	.0000045	.0000073	.0000114	.0000111
Ar	.0000013	.0000015	.0000027	.0000045	.0000073	.0000114	.0000111
CH ₄	.0000742	.0000697	.0000645	.0000602	.0000558	.0000471	.0000466
CM ₄	.0003923	.0002507	.0001633	.0001049	.0000715	.0000485	.0000522

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

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PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

12.6% NC

0.2

TEMP. °K	2000.00	2100.00	2200.00	2300.00	2400.00	2500.00	2600.00
MOL. WT.	24.8397	24.8108	24.7950	24.7846	24.7776	24.7696	24.7650
P	25154	26447	27724	29005	30280	31545	32812
e	- 930.81	- 895.90	- 861.10	- 826.54	- 791.82	- 756.66	- 721.44
CV	334945	337107	339659	341372	343427	345087	346507
γ	1.25562	1.25460	1.25101	1.24851	1.24554	1.24297	1.24067
E	2.00244	2.01947	2.03565	2.05104	2.06537	2.08020	2.09402
HF	471.90	505.82	539.71	573.39	607.50	641.66	676.05
	1459.27	1458.30	1457.39	1456.52	1455.92	1454.93	1454.10
CO	.0168453	.0169931	.0171101	.0172098	.0172717	.0173691	.0174323
CO2	.0051301	.0050052	.0049001	.0048078	.0047504	.0046576	.0045969
H2	.0045700	.0044792	.0043923	.0043110	.0042596	.0041730	.0041130
H2O	.0091902	.0093133	.0094178	.0095098	.0095670	.0096598	.0097190
N2	.0044765	.0044637	.0044833	.0044853	.0044866	.0044586	.0044888
O2							
OH	.0000001	.0000002	.0000004	.0000009	.0000016	.0000029	.0000050
H	.0000006	.0000010	.0000018	.0000030	.0000048	.0000073	.0000109
NO					.0000001	.0000002	.0000004
HCN							
CH4	.0000236	.0000239	.0000183	.0000163	.0000145	.0000118	.0000120
	.0000217	.0000117	.0000068	.0000043	.0000026	.0000016	.0000011

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

12.6% NC

0.2

TEMP. °K	2700.00	2800.00	2900.00	3000.00	3100.00	3200.00	3300.00
VOL. WT.	24.7579	24.7493	24.7403	24.7237	24.7057	24.6813	24.6510
P	34280	35348	36616	37888	39151	40438	41719
e	- 686.28	- 650.29	- 614.13	- 577.45	- 540.34	- 502.49	- 463.87
CV	347747	349202	350481	351554	352586	353652	354564
γ	1.23887	1.23678	1.23490	1.23326	1.23186	1.23040	1.22912
z	2.15737	2.12038	2.13307	2.14550	2.15765	2.16966	2.18153
z	710.54	745.37	780.39	815.75	851.23	887.05	923.15
MF	1453.24	1452.25	1451.14	1449.84	1448.21	1446.21	1443.71
CO	0.74332	0.75422	0.75854	0.76354	0.76794	0.77223	0.77670
CO2	0.05425	0.04946	0.04523	0.04130	0.03791	0.03451	0.03141
H2O	0.03005	0.02142	0.01975	0.01936	0.01904	0.01876	0.01855
H2	0.00770	0.00610	0.00529	0.00458	0.00391	0.00324	0.00264
N2	0.00439	0.00450	0.00460	0.00469	0.00479	0.00489	0.00498
O2	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
NO	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
HF	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
CH4	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C2H6	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C3H8	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C4H10	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C5H12	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C6H14	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C7H16	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C8H18	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C9H20	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C10H22	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C11H24	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C12H26	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C13H28	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C14H30	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C15H32	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C16H34	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C17H36	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C18H38	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C19H40	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C20H42	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C21H44	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C22H46	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C23H48	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C24H50	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C25H52	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C26H54	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C27H56	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C28H58	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C29H60	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C30H62	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C31H64	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C32H66	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C33H68	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C34H70	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C35H72	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C36H74	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C37H76	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C38H78	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C39H80	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C40H82	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C41H84	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C42H86	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C43H88	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C44H90	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C45H92	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C46H94	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C47H96	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C48H98	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C49H100	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C50H102	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C51H104	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C52H106	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C53H108	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C54H110	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C55H112	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C56H114	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C57H116	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C58H118	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C59H120	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C60H122	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C61H124	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C62H126	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C63H128	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C64H130	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C65H132	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C66H134	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C67H136	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C68H138	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C69H140	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C70H142	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C71H144	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C72H146	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C73H148	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C74H150	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C75H152	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C76H154	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C77H156	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C78H158	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C79H160	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C80H162	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C81H164	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C82H166	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C83H168	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C84H170	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C85H172	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C86H174	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C87H176	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C88H178	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C89H180	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C90H182	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C91H184	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C92H186	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C93H188	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C94H190	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C95H192	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C96H194	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C97H196	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C98H198	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C99H200	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C100H202	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000

0.2

153

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

12.8x NC

0.2

TEMP. °K	2700.00	2800.00	2900.00	3000.00	3100.00	3200.00	3300.00
NO. NT.	25.0245	25.0159	25.0066	24.9899	24.9713	24.9461	24.9146
P	33654	34548	36253	37461	38721	39985	41253
e	- 703.64	- 567.96	- 531.50	- 505.33	- 558.30	- 520.51	- 481.93
C _p	.345195	.348043	.349314	.350379	.351403	.352457	.353360
γ	1.23737	1.23529	1.23341	1.23178	1.23038	1.22892	1.22765
γ ₂	2.09529	2.10237	2.1102	2.11341	2.11554	2.11752	2.11939
γ ₃	728.04	742.77	777.68	812.93	848.31	884.03	920.04
γ ₄	1468.19	1467.24	1466.10	1464.79	1463.15	1461.11	1458.56

CO ₂	.009768	.0170230	.0170738	.0171204	.0171633	.0172074	.0172527
H ₂ O	.0248179	.0047708	.0047239	.0046897	.0046550	.0046219	.0045903
H ₂	.0037455	.0037027	.0036605	.0036260	.0035945	.0035679	.0035453
O ₂	.0058165	.0058607	.0058965	.0059287	.0059521	.0059697	.0059799
CO	.0045657	.0045665	.0045663	.0045681	.0045686	.0045697	.0045704
CH ₄	.0000001	.0000001	.0000001	.0000002	.0000003	.0000006	.0000011
CH ₃	.0000001	.0000001	.0000001	.0000002	.0000004	.0000009	.0000013
H ₂ O	.0000137	.0000137	.0000130	.0000130	.0000143	.0000143	.0000152
CO ₂	.0000212	.0000212	.0000210	.0000190	.0000155	.0000167	.0000130
CH ₄	.0000014	.0000014	.0000023	.0000037	.0000058	.0000088	.0000130
CH ₃	.0000002	.0000002	.0000003	.0000004	.0000007	.0000010	.0000015
CH ₂	.0000093	.0000093	.0000103	.0000082	.0000082	.0000074	.0000071
CH	.0000004	.0000004	.0000003	.0000002	.0000002	.0000002	.0000001

ANALYTICAL THERMODYNAMIC PROPERTIES AND COMPOSITION

0.2

12.50 10

0.00 0.00

3400.00

3500.00

3144.84

0.00 0.00

24.8731

24.8053

24.9503

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43.37

39287

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Q.2.

13.05 PC

TEMP. °N	2000.00	2100.00	220 .	2300 .	2400.00	2500.00	2600.00
25.3618	25.3424	25.3315	25.3241	25.3159	25.3084	25.3024	25.2964
24.520	24.5041	24.4896	24.4759	24.4624	24.4489	24.4354	24.4219
23.677	23.6622	23.6469	23.6317	23.6164	23.6011	23.5858	23.5705
22.834	22.8189	22.8036	22.7883	22.7730	22.7577	22.7424	22.7271
21.991	21.9756	21.9603	21.9450	21.9297	21.9144	21.8991	21.8838
21.148	21.1329	21.1176	21.1023	21.0870	21.0717	21.0564	21.0411
20.305	20.2896	20.2743	20.2590	20.2437	20.2284	20.2131	20.1978
19.462	19.4469	19.4316	19.4163	19.4010	19.3857	19.3704	19.3551
18.619	18.6036	18.5883	18.5730	18.5577	18.5424	18.5271	18.5118
17.776	17.7613	17.7460	17.7307	17.7154	17.6999	17.6846	17.6693
16.933	16.9179	16.9026	16.8873	16.8720	16.8567	16.8414	16.8261
16.090	16.0746	16.0593	16.0440	16.0287	16.0134	15.9981	15.9828
15.247	15.2314	15.2161	15.2008	15.1855	15.1702	15.1549	15.1396
14.404	14.3886	14.3733	14.3580	14.3427	14.3274	14.3121	14.2968
13.561	13.5457	13.5304	13.5151	13.4998	13.4845	13.4692	13.4539
12.718	12.7025	12.6872	12.6719	12.6566	12.6413	12.6260	12.6107
11.875	11.8596	11.8443	11.8290	11.8137	11.7984	11.7831	11.7678
11.032	11.0169	11.0016	10.9863	10.9710	10.9557	10.9404	10.9251
10.189	10.1736	10.1583	10.1430	10.1277	10.1124	10.0971	10.0818
9.346	9.3307	9.3154	9.2999	9.2846	9.2693	9.2540	9.2387
8.503	8.4879	8.4726	8.4573	8.4420	8.4267	8.4114	8.3961
7.660	7.6446	7.6293	7.6140	7.5987	7.5834	7.5681	7.5528
6.817	6.8018	6.7865	6.7712	6.7559	6.7406	6.7253	6.7100
5.974	5.9589	5.9436	5.9283	5.9130	5.8977	5.8824	5.8671
5.131	5.1157	5.1004	5.0851	5.0698	5.0545	5.0392	5.0239
4.288	4.2729	4.2576	4.2423	4.2270	4.2117	4.1964	4.1811
3.445	3.4296	3.4143	3.3990	3.3837	3.3684	3.3531	3.3378
2.602	2.5863	2.5710	2.5557	2.5404	2.5251	2.5098	2.4945
1.759	1.7439	1.7286	1.7133	1.6980	1.6827	1.6674	1.6521
0.916	0.9007	0.8854	0.8701	0.8548	0.8395	0.8242	0.8089
0.073	0.0574	0.0421	0.0268	0.0115	0.0000	0.0000	0.0000

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[illegible]

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.2

23.02 NC

TEMP. °K 3400.00 3500.00 3230.36

MOLE WT.
 S 25.1460 25.0938 25.2110
 - 42046 43315 39911
 - 46110 - 42051
 CV 332980 253800 351596
 1.22505 1.22413 1.22697
 2.16677 2.19053 2.14875
 953.26 989.72 892.02
 1479.86 1466.78 1476.02

CO2 .0166223 .0166846
 CO .0048228 .0049100
 H2O .0032176 .0032632
 H2 .0100042 .0100029
 O2 .0046415 .0046404
 N2 .0000056 .0000009
 H .0000040 .0000010
 I .0001690 .0000746
 O .0011274 .0000589
 F .0000250 .0000109
 Cl .0000032 .0000012
 Br .0000058 .0000064
 K .0000001 .0000001
 Na .0000001 .0000001

20

269

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

13.1% HC

C.2

TEMP. °K	1700.00	1800.00	1900.00	2000.00	3000.00	3100.00	3200.00	3300.00
AD. WT.	25.4352	25.4306	25.4207	25.4038	25.3841	25.3576	25.3245	
P	32115	34350	35585	36824	38064	39309	40558	
C _v	- 735.75	- 675.26	- 659.35	- 622.91	- 585.99	- 545.28	- 509.73	
7	34451	34638	34764	34869	34970	35074	35163	
8	1.2251	1.2229	1.2207	1.2184	1.2160	1.2136	1.2112	
9	2.1770	2.0897	2.1025	2.1149	2.1271	2.1389	2.1508	
10	774.47	734.05	773.81	808.91	844.15	879.74	915.63	
11	1451.01	1490.66	1489.52	1486.23	1486.52	1484.43	1481.79	
12	1617.35	162259	162089	163141	163558	164011	164473	
13	163045	163215	163177	163195	163195	163195	163195	
14	163337	163252	163218	163191	163155	163129	163103	
15	163815	163704	163683	163689	163699	163709	163719	
16	164372	164271	164249	164244	164249	164258	164263	
17		164301	164301	164302	164304	164309	164315	
18		164301	164301	164303	164305	164309	164315	
19		164346	164320	164335	164348	164363	164385	
20		164399	164372	164386	164397	164402	164415	
21		164416	164427	164443	164467	164482	164505	
22		164432	164435	164434	164437	164437	164439	
23		164437	164435	164434	164438	164438	164439	
24		164435	164435	164432	164438	164438	164439	

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

13.154 KC

0.2

TEMP. °C	2000.00	2100.00	2200.00	2300.00	2400.00	2500.00	2600.00
MO. WT.	25.5098	25.5532	25.5438	25.5372	25.5323	25.5260	25.5217
C	74362	25611	26855	28089	29324	30552	31782
H	777.48	743.49	709.67	674.71	640.30	605.56	570.86
N	321.949	331.517	336.661	338.302	340.403	342.037	343.439
O	1.45433	1.23220	1.24671	1.24419	1.24123	1.23567	1.23037
S	1.97008	1.98678	2.00273	2.01796	2.03217	2.04682	2.06051
Cl	407.94	501.24	584.0	667.97	751.74	835.57	919.08
Br	551.77	1500.73	1499.83	1490.59	1482.40	1477.44	1476.64
CO ₂	.0154420	.0155695	.0156742	.0157650	.0158319	.0159129	.0159724
CO	.0058925	.0057539	.0056855	.0055938	.0055447	.0054568	.0053993
H ₂ O	.0037375	.0036401	.0035512	.0034793	.0034195	.0033354	.0032781
H ₂	.0093162	.0094330	.0095321	.0096190	.0096729	.0097600	.0098166
O ₂	.0040822	.0046650	.0046898	.0046852	.0046592	.0046207	.0046909
H	.0000001	.0000002	.0000005	.0000010	.0000018	.0000033	.0000057
NO	.0000005	.0000009	.0000016	.0000027	.0000043	.0000065	.0000097
NO ₂	.0000000	.0000000	.0000000	.0000001	.0000001	.0000005	.0000005
NO ₂	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
Br ₂	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
Cl ₂	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

13.15% NC

0.2

TEMP. °K	2700.00	2800.00	2900.00	3000.00	3100.00	3200.00	3300.00
MOL. WT.	25.5149	25.5062	25.4962	25.4791	25.4593	25.4325	25.3985
O	32013	34244	35475	36711	37948	39185	40422
H	- 735.02	- 700.42	- 664.24	- 627.22	- 590.22	- 553.22	- 514.67
CV	344062	346000	347343	348402	349410	350448	351333
Y	1.23458	1.23251	1.23004	1.22901	1.22763	1.22618	1.22491
Z	2.37374	2.36505	2.35924	2.35157	2.34366	2.33562	2.32747
E	902.25	738.60	773.14	808.21	843.42	877.00	914.80
HF	1495.80	1494.95	1493.71	1492.28	1490.70	1488.59	1485.93
CO	0.62271	0.60765	0.591212	0.574066	0.556292	0.537935	0.519000
CO2	0.033476	0.035319	0.0362615	0.0372233	0.0381890	0.0391500	0.0401065
H2O	0.32278	0.334335	0.34453	0.354101	0.363082	0.371549	0.379535
H2	0.008660	0.009371	0.009920	0.0103720	0.010737	0.0110093	0.0112835
CH4	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
N2	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
NO	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
NO2	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
HCN	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
CH3	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
OH	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
HO2	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
H2O2	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
CH2	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
CH	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
C2H2	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
C2H4	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
C2H6	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
C2	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
C	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
CN	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

13.15% NC

0.2

TEMP. °K 3400.00 3500.00 3292.47

MOL. WT.

25.3555 25.3012 25.4013

e

4168 42945 40341

CV

- 434.30

7

352112 352973 351272

S

1.22387 1.22298 1.22501

TE

2.15530 2.17104 2.14658

957.01 997.44 912.15

1482.55 1478.40 1486.15

CO2

.0163508 .0164080 .012964

T2

.0050513 .0050571 .0051263

T3

.0030167 .0030045 .0030353

CO

.0100185 .0100119 .0100175

CH4

.0046958 .0046960 .0046955

H2O

.0000025 .0000041 .0000014

OT

.0000025 .0000043 .0000015

HC

.0000014 .0000015 .0000015

TS

.0000014 .0000015 .0000015

CH4

.0000014 .0000015 .0000015

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.2

13.2% NC

TEMP. °F.	2700.00	2800.00	2900.00	3000.00	3100.00	3200.00	3300.00
VOL. FT. ³	25.5825	25.5748	25.5647	25.5475	25.5275	25.5064	25.4866
P	32920	34149	35377	36609	37842	39081	40327
e	-740.14	-704.07	-668.90	-632.41	-595.51	-557.82	-519.27
CV	344417	345347	347100	348152	349158	350199	351177
γ	1.23418	1.23211	1.23023	1.22852	1.22723	1.22579	1.22433
Σ	2.07775	2.08368	2.09624	2.10857	2.12066	2.13261	2.14446
ΣE	703.32	757.84	772.58	807.61	842.80	878.36	914.21
ΣE	1459.76	1498.61	1497.67	1496.34	1494.65	1492.54	1489.93

CO ₂	0.58927	0.59418	0.59853	0.60315	0.60741	0.61155	0.61565
CO	0.014245	0.023791	0.033285	0.043009	0.052627	0.062236	0.071835
H ₂ O	0.031600	0.031160	0.030762	0.030431	0.030135	0.029895	0.029675
H ₂	0.058708	0.0595123	0.0599461	0.0599759	0.0599973	0.0600128	0.0600253
O ₂	0.07073	0.047030	0.047079	0.047093	0.047098	0.047106	0.047111
NO		0.000001	0.000001	0.000002	0.000005	0.000009	0.000013
HF		0.000001	0.000001	0.000003	0.000005	0.000005	0.000003
CH ₄	0.000394	0.000155	0.000230	0.000343	0.000498	0.000706	0.000979
N ₂	0.000135	0.000194	0.000266	0.000357	0.000471	0.000610	0.000779
Ar	0.000010	0.000017	0.000028	0.000045	0.000071	0.000107	0.000158
Σ	0.000001	0.000002	0.000003	0.000004	0.000007	0.000013	0.000023
CH ₃	0.000077	0.000072	0.000065	0.000064	0.000063	0.000062	0.000061
CH ₂	0.000003	0.000002	0.000002	0.000001	0.000001	0.000001	0.000001

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.2

13.2% NC

TEMP. °K	3400.00	3500.00	3617.01
MOL. WT.	25.4226	25.3675	25.4554
D	41571	42828	40535
e	- 475.74	- 439.07	
CV	33353	352710	351216
γ	1.22348	1.22257	1.22434
Σ	2.15626	2.15504	2.14647
Σ	540.35	536.76	520.34
Σ	1466.40	1482.27	1469.24

CO	0.02162	0.02739	0.01734
CO2	0.05187	0.051341	0.051960
H2	0.02557	0.029386	0.029644
H2O	0.00216	0.00143	0.00215
O2	0.047114	0.047116	0.047112
N2	0.00026	0.00043	0.00017
NO	0.00027	0.00044	0.00018
HF	0.00029	0.001770	0.001032
Cl2	0.00960	0.001215	0.000811
Br2	0.00027	0.000325	0.000169
I2	0.00023	0.000032	0.000016
HCN	0.00054	0.000051	0.000054
CH4	0.00001	0.000001	0.000001

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

CH N3 100% HC

0.1

TEMP. °K	3000.00	3100.00	3200.00	3300.00	3400.00	3500.00	3600.00
ΔH _f AT.	25.4434	25.4290	25.2810	25.3308	25.2668	25.1860	25.0859
ΔG _f	16067	16614	17165	17720	18279	18846	19421
ΔG _f	- 625.24	- 587.62	- 548.98	- 509.37	- 467.73	- 424.66	- 379.47
CV	145957	147020	148046	148947	149764	150564	151341
γ	1.22809	1.22763	1.22660	1.22574	1.22505	1.22453	1.22408
ΔH _c	2.17734	2.18960	2.20193	2.21420	2.22654	2.23901	2.25174
ΔH _c	811.75	846.98	882.60	918.30	955.01	991.86	1029.27
ΔH _c	1493.35	1490.98	1487.97	1484.12	1479.22	1473.05	1465.35

CO	1159312	1159310	1160341	1160920	1161576	1162339	1163237
CO2	1154713	1154339	1153972	1153606	1153221	1152832	1152435
H2	1133631	1133315	1133050	1132837	1132677	1132582	1132557
H2O	1197154	1197348	1197463	1197485	1197410	1197225	1196917
H2	1146973	1146980	1146990	1146998	1147005	1147010	1147015
O2	1111133	1111111	1111019	1111033	1111057	1111093	1111147
O2	1111116	1111011	1110919	1110834	1110757	1110693	1110645
OH	1100485	1100373	1100295	1100236	1100184	1100146	1100121
H	1100560	1100378	1100257	1100121	1100038	1100012	1100052
H2O	1100064	1100099	1100150	1100221	1100317	1100444	1100609
NH3	1100006	1100009	1100015	1100022	1100032	1100046	1100065
CH4	11000128	1100025	1100025	1100024	1100024	1100022	1100021

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

C.I.

O% NG 100% NC

TEMP. °K	3700.00	3800.00	3900.00	4000.00	3247.24
MOL. WT.	24.9630	24.8152	24.6395	24.4338	25.3587
P	20006	20604	21215	21843	17426
e	- 332.03	- 281.58	- 228.55	- 172.08	
CV	.352027	.352619	.352266	.352656	.348488
γ	1.22375	1.22362	1.22460	1.22503	1.22618
S	2.26478	2.27818	2.29195	2.30625	2.20772
E	1067.07	1105.78	1144.62	1184.18	899.56
HF	1455.77	1444.15	1430.08	1413.29	1486.26
CO	.0164329	.0165580	.0167078	.0168841	.0160608
CO2	.0051771	.0051163	.0050437	.0049587	.0053799
H2O	.0032594	.0032760	.0033017	.0033388	.0032942
H2	.0096492	.0095883	.0095123	.0094189	.0097486
O2	.0047015	.0047010	.0047003	.0046992	.0046994
NO	.0002226	.0002326	.0002465	.0002680	.0002025
CH4	.0002226	.0002342	.0002499	.0002712	.0002025
CH2	.0004146	.0004230	.0004500	.0004958	.0004163
HCN	.0002663	.0002457	.0004141	.0004927	.0004076
N2	.0000518	.0001076	.0001389	.0001761	.0000181
HF	.0000389	.0000121	.0000161	.0000212	.0000018
CH3	.0000021	.0000020	.0000020	.0000021	.0000024

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

OR NG 2001 NC 0.25

TEMP. °F.	5000.00	3100.00	3200.00	3300.00	3400.00	3500.00	3600.00
ρ	25.4670	25.4436	25.4123	25.3723	25.3214	25.2575	25.1773
e	25739	26611	27456	28367	29253	30146	31046
Cv	- 325.93	- 355.30	- 551.76	- 512.77	- 472.65	- 431.09	- 390.00
γ	1.22378	1.22754	1.22628	1.22520	1.22430	1.22355	1.22281
Σ	2.13927	2.15234	2.16410	2.17609	2.18809	2.20011	2.21211
HF	639.61	845.00	860.55	916.43	952.64	989.19	1025.61
	1403.11	1491.27	1488.72	1485.62	1481.69	1476.76	1471.83

CO ₂	16.0415	16.0885	16.1358	16.1866	16.2431	16.3075	16.3765
CO	1.3325	1.3315	1.3305	1.3295	1.3285	1.3275	1.3265
H ₂ O	12.421	12.4212	12.4213	12.4214	12.4215	12.4216	12.4217
H ₂	1.3333	1.3334	1.3335	1.3336	1.3337	1.3338	1.3339
N ₂	1.3334	1.3335	1.3336	1.3337	1.3338	1.3339	1.3340
O ₂	1.3335	1.3336	1.3337	1.3338	1.3339	1.3340	1.3341
CH ₄	1.3341	1.3342	1.3343	1.3344	1.3345	1.3346	1.3347
HCN	1.3347	1.3348	1.3349	1.3350	1.3351	1.3352	1.3353

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

OX NS 100% NC 0.15

TEMP. °K	3700.00	3800.00	3900.00	4000.00	3255.40
MOL. WT.	25.0604	24.9630	24.8230	24.6534	25.3912
P	31966	32897	33842	34877	27974
e	- 342.81	- 295.31	- 245.97	- 193.69	
CV	353373	354047	353326	352796	349741
Y	1.22217	1.22171	1.22275	1.22284	1.22566
Z	2.22466	2.23727	2.25009	2.26533	2.17075
W	1903.84	1901.85	189.98	173.88	950.33
HF	1463.05	1455.55	1442.73	1429.45	1487.09
CO	0.165713	0.165722	0.166922	0.168332	0.161636
CO2	0.050530	0.050378	0.049787	0.049098	0.052634
H2	0.031283	0.031383	0.031565	0.031827	0.031725
H2O	0.099153	0.097694	0.097097	0.096356	0.098789
NO	0.046978	0.046970	0.046956	0.046938	0.046972
NO2	0.001144	0.002216	0.003314	0.004445	0.006016
SO2	0.001145	0.002222	0.003326	0.004467	0.006017
SO3	0.003400	0.004300	0.005360	0.006557	0.008072
H	0.02233	0.022693	0.023221	0.023825	0.024593
O	0.006672	0.006884	0.007145	0.007459	0.007811
N	0.000072	0.000098	0.000131	0.000173	0.000215
CH4	0.000034	0.000033	0.000033	0.000033	0.000034

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

5% NG 95% NC

0.1

TEMP. °K	3000.00	3100.00	3200.00	3300.00	3400.00	3500.00	3600.00
MOL. WT.	25.7211	25.6901	25.6488	25.5953	25.5269	25.4401	25.3321
P	15889	15431	16976	17526	18081	18643	19215
e	- 650.15	- 612.40	- 573.55	- 535.40	- 491.70	- 448.14	- 402.32
CV	345376	347135	348156	349049	349855	350640	351398
T	1.22640	1.22535	1.22434	1.22349	1.22282	1.22233	1.22189
S	2.16066	2.17925	2.19158	2.20392	2.21637	2.22899	2.24183
E	811.64	846.93	882.62	918.73	955.26	992.27	1029.87
HF	1518.44	1516.00	1512.88	1508.67	1503.73	1497.25	1489.13
CO	.0151558	.0152059	.0152640	.0153239	.0153927	.0154738	.0155703
CO2	.0058352	.0057977	.0057605	.0057226	.0056819	.0056368	.0055852
H2	.0030652	.0030351	.0030100	.0029952	.0029762	.0029688	.0029688
H2O	.0095086	.0095265	.0095364	.0095369	.0095274	.0095067	.0094735
N2	.0047929	.0047936	.0047945	.0047952	.0047957	.0047961	.0047961
O2	.0000007	.0000013	.0000024	.0000042	.0000071	.0000116	.0000184
OH	.0000006	.0000012	.0000022	.0000038	.0000064	.0000104	.0000163
CH	.0000516	.0000752	.0001063	.0001470	.0001991	.0002644	.0003448
H	.0000535	.0000735	.0000913	.0001165	.0001467	.0001825	.0002246
NC	.0000072	.0000112	.0000170	.0000250	.0000358	.0000502	.0000688
N	.0000006	.0000010	.0000015	.0000022	.0000032	.0000046	.0000065
NH3	.0000024	.0000024	.0000022	.0000021	.0000021	.0000020	.0000019
CH4			.0000022				

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

50 MG 95% HC 0.1

TEMP. °K	3700.00	3800.00	3900.00	4000.00	3336.07
MOLE WT.	25.1994	25.0395	24.8493	24.6269	25.5724
1	1977	20393	21003	21631	17725
2	354.04	- 332.61	- 248.39	- 190.50	
3	1350.09	1352.62	1352.22	1352.57	1349351
4	122.65	122.39	122.22	122.13	1.22323
5	122.65	122.39	122.22	122.13	2.20840
6	122.65	122.39	122.22	122.13	931.65
7	122.65	122.39	122.22	122.13	1507.15
8	122.65	122.39	122.22	122.13	
9	122.65	122.39	122.22	122.13	
10	122.65	122.39	122.22	122.13	
11	122.65	122.39	122.22	122.13	
12	122.65	122.39	122.22	122.13	
13	122.65	122.39	122.22	122.13	
14	122.65	122.39	122.22	122.13	
15	122.65	122.39	122.22	122.13	
16	122.65	122.39	122.22	122.13	
17	122.65	122.39	122.22	122.13	
18	122.65	122.39	122.22	122.13	
19	122.65	122.39	122.22	122.13	
20	122.65	122.39	122.22	122.13	
21	122.65	122.39	122.22	122.13	
22	122.65	122.39	122.22	122.13	
23	122.65	122.39	122.22	122.13	
24	122.65	122.39	122.22	122.13	
25	122.65	122.39	122.22	122.13	
26	122.65	122.39	122.22	122.13	
27	122.65	122.39	122.22	122.13	
28	122.65	122.39	122.22	122.13	
29	122.65	122.39	122.22	122.13	
30	122.65	122.39	122.22	122.13	
31	122.65	122.39	122.22	122.13	
32	122.65	122.39	122.22	122.13	
33	122.65	122.39	122.22	122.13	
34	122.65	122.39	122.22	122.13	
35	122.65	122.39	122.22	122.13	
36	122.65	122.39	122.22	122.13	
37	122.65	122.39	122.22	122.13	
38	122.65	122.39	122.22	122.13	
39	122.65	122.39	122.22	122.13	
40	122.65	122.39	122.22	122.13	
41	122.65	122.39	122.22	122.13	
42	122.65	122.39	122.22	122.13	
43	122.65	122.39	122.22	122.13	
44	122.65	122.39	122.22	122.13	
45	122.65	122.39	122.22	122.13	
46	122.65	122.39	122.22	122.13	
47	122.65	122.39	122.22	122.13	
48	122.65	122.39	122.22	122.13	
49	122.65	122.39	122.22	122.13	
50	122.65	122.39	122.22	122.13	

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

5% NO 95% C

0.15

TEMP, °K	3000.00	3100.00	3200.00	3300.00	3400.00	3500.00	3600.00
h _f	25.7390	25.7143	25.6812	25.6386	25.5843	25.5156	25.4300
e	25449	26312	27160	28052	28930	29817	30715
CV	- 651.96	- 614.73	- 576.56	- 537.34	- 496.88	- 454.97	- 411.22
T ₁	347272	348307	349338	350229	351022	351847	352680
T ₂	1.22657	1.22533	1.22408	1.22301	1.22212	1.22140	1.22066
T ₃	2.12575	2.14199	2.15410	2.16616	2.17823	2.19037	2.20269
T ₄	809.65	844.80	880.51	916.47	952.79	989.47	1026.69
HF	1516.28	1510.28	1513.75	1510.51	1506.41	1501.23	1494.76

CO	0.022059	0.015316	0.0103600	0.0154122	0.0154709	0.0155388	0.0156185
CO ₂	0.057217	0.056661	0.055513	0.056165	0.055800	0.055405	0.054965
H ₂	0.029472	0.029195	0.028948	0.028746	0.028591	0.028493	0.028455
H ₂ O	0.02285	0.020622	0.010612	0.010660	0.010623	0.010493	0.010228
O ₂	0.047912	0.047316	0.047925	0.047930	0.047933	0.047934	0.047931
N ₂	0.000004	0.000008	0.000015	0.000026	0.000045	0.000074	0.000117
HF	0.000004	0.000008	0.000014	0.000024	0.000041	0.000067	0.000107
NO	0.000421	0.000511	0.000625	0.000719	0.000824	0.000961	0.001170
NH ₃	0.000418	0.000551	0.000713	0.000910	0.001145	0.001424	0.001750
HCN	0.000398	0.000591	0.000738	0.000923	0.001092	0.001349	0.001653
CH ₄	0.000345	0.000508	0.000612	0.000708	0.000826	0.000938	0.001053
	0.000301	0.000339	0.000336	0.000334	0.00033	0.000332	0.000330

THEORY OF PROPERTIES AND COMPOSITION OF DIRECTED GAS COMPOSITION

2000

47
-6
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(7)

3500.00	4000.00	3546.77
25.040	2.8678	25.6148
3349	34450	28462
20.000	2.0000	20.0000
3333.33	3337.48	3333.33
1.0000	1.0000	1.0000
2.0000	2.0000	2.0000
3.0000	3.0000	3.0000
4.0000	4.0000	4.0000
5.0000	5.0000	5.0000
6.0000	6.0000	6.0000
7.0000	7.0000	7.0000
8.0000	8.0000	8.0000
9.0000	9.0000	9.0000
10.0000	10.0000	10.0000
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81.0000	81.0000	81.0000
82.0000	82.0000	82.0000
83.0000	83.0000	83.0000
84.0000	84.0000	84.0000
85.0000	85.0000	85.

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

102 HG 90% NC 0.1

TEMP. °K	3000.00	3100.00	3200.00	3300.00	3400.00	3500.00	3600.00
MOLE WT.	25.9964	25.9655	25.9215	25.8642	25.7906	25.6970	25.5301
P	15711	16248	16788	17333	17884	18443	19011
CV	- 675.08	- 637.17	- 598.12	- 557.67	- 515.54	- 471.42	- 424.87
γ	.346225	.347281	.348297	.349183	.349976	.350745	.351481
S	1.22409	1.22305	1.22205	1.22122	1.22058	1.22011	1.21972
E	2.15623	2.16854	2.18104	2.19348	2.20605	2.21883	2.23194
HF	511.83	646.99	822.77	918.95	955.67	992.86	1030.09
	1543.66	1541.11	1537.89	1533.69	1528.30	1521.43	1512.76

CO ₂	.0143735	.0144240	.0144792	.0145414	.0146140	.0147006	.0148049
CO	.0112.40	.0061760	.0061388	.0060994	.0060563	.0060073	.0059503
H ₂ O	.0027826	.0027540	.0027306	.0027127	.0027007	.0026955	.0026982
H ₂	.0008607	.00081025	.00071159	.00061095	.00050979	.00040749	.00030351
O ₂	.0048885	.0048692	.0048489	.0048285	.004808	.00478910	.0047705
N ₂	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
CH ₄	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
HCN	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
HF	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
OH	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
NO	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
CO ₂	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
CH ₄	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000

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b7

TABLE 1. THERMODYNAMIC PROPERTIES AND COMPOSITION GAS COMPOSITION

2455 2140

0.15

[illegible]

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

FOR 90% HIC 0.15

TEMP. °A	3700.00	3800.00	3900.00	4000.00	3433.79
Wt.	25.5706	25.4326	25.2676	25.0733	25.8284
P	31268	32210	33149	34011	28928
Q	357.97	- 338.78	- 287.38	- 232.66	
C _p	.353499	.354121	.353322	.353715	.351422
Y	1.21797	1.21760	1.21870	1.21809	1.21967
Z	2.22071	2.21878	2.23213	2.24598	2.17234
W	1265.13	1173.61	1142.47	1181.96	965.48
W ₂	1510.52	1459.91	1487.28	1472.19	1529.48
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PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

15% NO 85% NC

0.1

TEMP. °K	3000.00	3100.00	3200.00	3300.00	3400.00	3500.00	3600.00
MOL. WT.							
P	25.2814	26.2463	26.1992	26.1376	26.0579	25.9563	25.8289
Q	15535	16056	16602	17142	17689	18244	18810
CV	- 700.54	- 661.37	- 622.65	- 581.84	- 539.23	- 494.46	- 447.07
Y	.146405	.347458	.348469	.349347	.350125	.350876	.351588
S	1.22175	1.22073	1.21974	1.21893	1.21832	1.21789	1.21754
E	2.14536	2.15784	2.17051	2.18286	2.19558	2.20855	2.22189
HF	811.72	847.15	863.05	919.40	956.26	993.66	1031.75
	1568.99	1566.39	1562.99	1558.57	1552.87	1545.57	1536.25

CO	.1135725	.0136234	.0136800	.0137449	.0138219	.0139150	.0140283
CO2	.0066076	.0063702	.0065317	.0064906	.0064446	.0063912	.0063275
H2	.0125147	.0124881	.0124666	.0124507	.0124408	.0124361	.0124338
H2O	.0102455	.0102638	.0102699	.0102663	.0102526	.0102272	.0101868
N2	.0049841	.0049846	.0049833	.0049856	.0049858	.0049858	.0049854
O2	.0000111	.0000021	.0000028	.0000067	.0000113	.0000185	.0000291
OH	.0000008	.0000015	.0000027	.0000048	.0000080	.0000131	.0000206
H	.0000592	.0000859	.0001214	.0001679	.0002272	.0003014	.0003925
H2O	.0000484	.0000636	.0000827	.0001055	.0001329	.0001655	.0002035
N	.0000593	.0000744	.0000918	.000121	.000161	.0002044	.0002581
NO	.0000006	.0000010	.0000015	.0000023	.0000033	.0000047	.0000066
NO2	.0000018	.0000019	.0000017	.0000016	.0000016	.0000015	.0000014

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.1

15% AG 65% TC

TEMP. °K	3700.00	3800.00	3900.00	4000.00	3498.51
1	25.6716	25.4322	25.2556	24.9946	25.9580
2	19383	19922	20591	21229	18256
3	356.78	342.94	285.95	- 224.70	
4	352.89	352.67	352.130	352.432	350855
5	352.70	352.747	352.1865	352.1909	1.21790
6	352.57	352.57	352.26464	352.28032	2.20935
7	352.38	352.38	352.45.85	352.195.49	93.10
8	352.35	352.35	352.493.63	352.1473.29	1545.70
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PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.15

15% I.O 65% H.C

TEMP. °F.	3000.00	3100.00	3200.00	3300.00	3400.00	3500.00	3600.00
H ₂ O	26.3152	26.2723	26.2348	26.1859	26.1229	26.0425	25.9418
H	24.676	25.725	26.575	27.432	28.295	29.169	30.055
O	702.13	- 664.62	- 626.07	- 586.33	- 545.15	- 502.25	- 457.30
CO	1476.64	1460.33	1446.58	1434.35	1423.11	1412.09	1401.27
CO ₂	1.2220	1.2205	1.2191	1.2177	1.2171	1.2170	1.2163
N ₂	2.1035	2.1028	2.1021	2.1014	2.1002	2.1003	2.1003
N	854.05	845.02	835.85	826.57	817.55	808.36	800.13
H ₂	1565.00	1566.88	1564.14	1560.60	1556.04	1550.25	1542.94

CO	1346.60	1337.18	1327.61	1318.173	1308.820	1299.569	1290.314
CO ₂	1365.67	1356.17	1346.364	1336.396	1326.359	1316.337	1306.329
CO ₂	1324.00	1314.42	1304.803	1295.456	1286.236	1277.275	1268.380
CO ₂	1333.33	1323.747	1314.141	1304.553	1295.079	1285.718	1276.370
CO ₂	1343.27	1333.593	1323.837	1314.083	1304.536	1295.233	1285.983
CO ₂	1353.27	1343.424	1333.504	1323.542	1313.607	1303.713	1293.859
CO ₂	1363.35	1353.318	1343.118	1332.831	1322.552	1312.285	1302.033
CO ₂	1373.48	1363.265	1352.989	1342.669	1332.355	1322.066	1311.793
CO ₂	1383.78	1373.497	1363.144	1352.782	1342.435	1332.127	1321.835
CO ₂	1394.15	1383.817	1373.418	1362.962	1352.526	1342.128	1331.724
CO ₂	1404.55	1394.158	1383.712	1373.268	1362.847	1352.458	1342.054
CO ₂	1415.00	1404.553	1394.112	1383.685	1373.282	1362.903	1352.503

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.15

15% NG 85% NC

TEMP. °K	3700.00	3800.00	3900.00	4000.00	3516.12
MOL. WT.	25.8172	25.6664	25.4863	25.2748	25.2277
P	30950	31875	32812	33773	2931:
Q	- 410.02	- 359.80	- 307.16	- 251.00	
CV	352502	354192	353351	353700	352238
γ	1.21586	1.21554	1.21678	1.21709	1.21692
Δ	2.19609	2.20543	2.22310	2.23732	2.17246
Δ	1066.24	1125.21	1144.20	1184.04	996.58
HF	1522.80	1522.65	1509.12	1492.95	1549.18
CO	0.141647	0.142969	0.144560	0.146442	0.139726
CO2	0.061961	0.061235	0.060265	0.059338	0.063056
H2O	0.022342	0.023521	0.023789	0.024160	0.023271
H2	0.002951	0.002409	0.001733	0.000907	0.003571
O2	0.049312	0.049794	0.049771	0.049743	0.049832
CH4	0.000288	0.000428	0.000614	0.000957	0.000128
CH	0.000208	0.000312	0.000456	0.000549	0.000092
H	0.004133	0.005214	0.006461	0.007956	0.002578
N2	0.001929	0.002353	0.002800	0.003339	0.001331
NO	0.000012	0.0001277	0.0001645	0.0002080	0.000056
OH	0.000074	0.000101	0.000135	0.000178	0.000041
HCN	0.000022	0.000022	0.000022	0.000022	0.000024

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

20% NG 80% NC

O.I

TEMP. °A	3000.00	3100.00	3200.00	3300.00	3400.00	3500.00	3600.00
P	26.5101	26.5325	26.4818	26.4151	26.3283	26.2172	26.0777
ρ	15359	15826	16416	16952	17495	18047	18611
C _p	- 725.01	- 686.73	- 647.12	- 605.90	- 562.72	- 517.20	- 468.83
γ	346615	347665	348670	349538	350301	351031	351715
ΔH _f	1.21942	1.21829	1.21742	1.21652	1.21605	1.21566	1.21537
ΔH _c	2.13429	2.14683	2.15940	2.17207	2.18496	2.19815	2.2117
ΔH _o	811.51	847.45	883.46	919.57	957.03	994.68	1033.77
ΔH _g	1554.45	1591.73	1588.17	1582.50	1577.43	1569.64	1559.75
ΔH _h	1.27372	1.25086	1.28665	1.29350	1.30172	1.31181	1.32421
ΔH _i	1.70157	1.65782	1.69385	1.68958	1.68463	1.67875	1.67166
ΔH _j	1.22619	1.22372	1.22178	1.22041	1.21966	1.21965	1.21965
ΔH _k	1.13470	1.13097	1.104135	1.104078	1.103917	1.103639	1.103220
ΔH _l	1.050764	1.045801	1.050805	1.051808	1.050897	1.050825	1.050759
ΔH _m	1.001119	1.001226	1.000048	1.000085	1.000144	1.000235	1.000365
ΔH _n	1.001119	1.001226	1.000048	1.000085	1.000144	1.000235	1.000365
ΔH _o	1.000634	1.000919	1.001299	1.001795	1.002428	1.003219	1.004253
ΔH _p	1.000450	1.000635	1.000784	1.001001	1.001261	1.001571	1.001937
ΔH _q	1.000126	1.000164	1.000249	1.000366	1.000524	1.000732	1.000999
ΔH _r	1.000000	1.000000	1.000015	1.000023	1.000033	1.000048	1.000067
ΔH _s	1.000000	1.000016	1.000014	1.000014	1.000013	1.000013	1.000012

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

20° K 500 K 0.1

TEMP. °K	3700.00	3800.00	3900.00	4000.00	3570.40
25.0051	25.6973	25.4512	25.1058	26.1222	
10.89	19.781	20.392	21024	18443	
4.73	-1362.52	-303.23	-240.19		
35228	352724	352179	352367	351518	
21526	1.21545	1.21777	1.21759	1.21544	
2.22491	2.24051	2.25528	2.27184	2.20768	
1.77	1.12.07	1152.35	1491.41	1021.62	
1547.15	1532.10	1511.86	1492.28	1562.52	
2133569	2133793	2137955	21405564	2132027	
2066285	2065266	2064067	2062602	2067390	
207215	2072525	2072847	2073534	2072014	
2072007	2071944	2071875	2071812	2073365	
2072007	2072773	2072767	2072755	2075801	
2072007	2072815	20728148	2072869	2070924	
2072007	2072532	2072777	2072085	2070205	
2072007	2072725	2072531	2072111	2073851	
2072007	207272	2072462	2072148	2071822	
2072007	2072727	2072218	2072775	2070913	
2072007	2072725	2072168	2072221	2070061	
2072007	2072725	2072012	2072012	2070012	

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

20% H₂ 30% NO

C.I.5

TEMP. °K	3000.00	3100.00	3200.00	3300.00	3400.00	3500.00	3600.00
1	26.5847	26.5598	26.5193	26.4667	26.3981	26.3104	26.2104
2	24.951	24.922	24.870	24.795	24.702	24.590	24.450
3	22.224	22.187	22.134	22.067	21.982	21.870	21.720
4	19.478	19.434	19.371	19.289	19.189	19.064	18.904
5	16.720	16.669	16.606	16.524	16.424	16.299	16.139
6	13.951	13.892	13.819	13.729	13.624	13.499	13.339
7	11.182	11.117	11.034	10.934	10.819	10.684	10.524
8	8.413	8.342	8.250	8.139	8.009	7.864	7.694
9	5.644	5.567	5.464	5.339	5.194	5.029	4.844
10	2.875	2.792	2.684	2.554	2.404	2.229	2.034
11	0.106	0.019	-0.064	-0.139	-0.214	-0.289	-0.364
12	0.000	0.000	0.000	0.000	0.000	0.000	0.000
13	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14	0.000	0.000	0.000	0.000	0.000	0.000	0.000
15	0.000	0.000	0.000	0.000	0.000	0.000	0.000
16	0.000	0.000	0.000	0.000	0.000	0.000	0.000
17	0.000	0.000	0.000	0.000	0.000	0.000	0.000
18	0.000	0.000	0.000	0.000	0.000	0.000	0.000
19	0.000	0.000	0.000	0.000	0.000	0.000	0.000
20	0.000	0.000	0.000	0.000	0.000	0.000	0.000
21	0.000	0.000	0.000	0.000	0.000	0.000	0.000
22	0.000	0.000	0.000	0.000	0.000	0.000	0.000
23	0.000	0.000	0.000	0.000	0.000	0.000	0.000
24	0.000	0.000	0.000	0.000	0.000	0.000	0.000
25	0.000	0.000	0.000	0.000	0.000	0.000	0.000
26	0.000	0.000	0.000	0.000	0.000	0.000	0.000
27	0.000	0.000	0.000	0.000	0.000	0.000	0.000
28	0.000	0.000	0.000	0.000	0.000	0.000	0.000
29	0.000	0.000	0.000	0.000	0.000	0.000	0.000
30	0.000	0.000	0.000	0.000	0.000	0.000	0.000
31	0.000	0.000	0.000	0.000	0.000	0.000	0.000
32	0.000	0.000	0.000	0.000	0.000	0.000	0.000
33	0.000	0.000	0.000	0.000	0.000	0.000	0.000
34	0.000	0.000	0.000	0.000	0.000	0.000	0.000
35	0.000	0.000	0.000	0.000	0.000	0.000	0.000
36	0.000	0.000	0.000	0.000	0.000	0.000	0.000
37	0.000	0.000	0.000	0.000	0.000	0.000	0.000
38	0.000	0.000	0.000	0.000	0.000	0.000	0.000
39	0.000	0.000	0.000	0.000	0.000	0.000	0.000
40	0.000	0.000	0.000	0.000	0.000	0.000	0.000
41	0.000	0.000	0.000	0.000	0.000	0.000	0.000
42	0.000	0.000	0.000	0.000	0.000	0.000	0.000
43	0.000	0.000	0.000	0.000	0.000	0.000	0.000
44	0.000	0.000	0.000	0.000	0.000	0.000	0.000
45	0.000	0.000	0.000	0.000	0.000	0.000	0.000
46	0.000	0.000	0.000	0.000	0.000	0.000	0.000
47	0.000	0.000	0.000	0.000	0.000	0.000	0.000
48	0.000	0.000	0.000	0.000	0.000	0.000	0.000
49	0.000	0.000	0.000	0.000	0.000	0.000	0.000
50	0.000	0.000	0.000	0.000	0.000	0.000	0.000
51	0.000	0.000	0.000	0.000	0.000	0.000	0.000
52	0.000	0.000	0.000	0.000	0.000	0.000	0.000
53	0.000	0.000	0.000	0.000	0.000	0.000	0.000
54	0.000	0.000	0.000	0.000	0.000	0.000	0.000
55	0.000	0.000	0.000	0.000	0.000	0.000	0.000
56	0.000	0.000	0.000	0.000	0.000	0.000	0.000
57	0.000	0.000	0.000	0.000	0.000	0.000	0.000
58	0.000	0.000	0.000	0.000	0.000	0.000	0.000
59	0.000	0.000	0.000	0.000	0.000	0.000	0.000
60	0.000	0.000	0.000	0.000	0.000	0.000	0.000
61	0.000	0.000	0.000	0.000	0.000	0.000	0.000
62	0.000	0.000	0.000	0.000	0.000	0.000	0.000
63	0.000	0.000	0.000	0.000	0.000	0.000	0.000
64	0.000	0.000	0.000	0.000	0.000	0.000	0.000
65	0.000	0.000	0.000	0.000	0.000	0.000	0.000
66	0.000	0.000	0.000	0.000	0.000	0.000	0.000
67	0.000	0.000	0.000	0.000	0.000	0.000	0.000
68	0.000	0.000	0.000	0.000	0.000	0.000	0.000
69	0.000	0.000	0.000	0.000	0.000	0.000	0.000
70	0.000	0.000	0.000	0.000	0.000	0.000	0.000
71	0.000	0.000	0.000	0.000	0.000	0.000	0.000
72	0.000	0.000	0.000	0.000	0.000	0.000	0.000
73	0.000	0.000	0.000	0.000	0.000	0.000	0.000
74	0.000	0.000	0.000	0.000	0.000	0.000	0.000
75	0.000	0.000	0.000	0.000	0.000	0.000	0.000
76	0.000	0.000	0.000	0.000	0.000	0.000	0.000
77	0.000	0.000	0.000	0.000	0.000	0.000	0.000
78	0.000	0.000	0.000	0.000	0.000	0.000	0.000
79	0.000	0.000	0.000	0.000	0.000	0.000	0.000
80	0.000	0.000	0.000	0.000	0.000	0.000	0.000
81	0.000	0.000	0.000	0.000	0.000	0.000	0.000
82	0.000	0.000	0.000	0.000	0.000	0.000	0.000
83	0.000	0.000	0.000	0.000	0.000	0.000	0.000
84	0.000	0.000	0.000	0.000	0.000	0.000	0.000
85	0.000	0.000	0.000	0.000	0.000	0.000	0.000
86	0.000	0.000	0.000	0.000	0.000	0.000	0.000
87	0.000	0.000	0.000	0.000	0.000	0.000	0.000
88	0.000	0.000	0.000	0.000	0.000	0.000	0.000
89	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90	0.000	0.000	0.000	0.000	0.000	0.000	0.000
91	0.000	0.000	0.000	0.000	0.000	0.000	0.000
92	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93	0.000	0.000	0.000	0.000	0.000	0.000	0.000
94	0.000	0.000	0.000	0.000	0.000	0.000	0.000
95	0.000	0.000	0.000	0.000	0.000	0.000	0.000
96	0.000	0.000	0.000	0.000	0.000	0.000	0.000
97	0.000	0.000	0.000	0.000	0.000	0.000	0.000
98	0.000	0.000	0.000	0.000	0.000	0.000	0.000
99	0.000	0.000	0.000	0.000	0.000	0.000	0.000
100	0.000	0.000	0.000	0.000	0.000	0.000	0.000

PROPERTIES, THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

2018-01-01

510

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POLYMERIZATION PROPERTIES AND COMBUSTION GAS COMPOSITION

340 75301

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PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

IDEAL GAS 0.2

TEMP. °C	1900.00	2000.00	2100.00	2200.00	2300.00	2400.00	2500.00
Wt. %	22.4063	22.4207	22.2847	22.2090	22.1619	22.1138	22.1111
Wt. %	21.447	21.617	21.841	21.775	21.710	21.651	21.604
Wt. %	21.100	21.177	21.111	21.040	20.975	20.919	20.862
Wt. %	20.747	20.823	20.757	20.687	20.622	20.567	20.510
Wt. %	20.394	20.470	20.404	20.334	20.269	20.214	20.157
Wt. %	19.941	19.917	19.893	19.869	19.845	19.821	19.797
Wt. %	19.488	19.464	19.440	19.416	19.392	19.368	19.344
Wt. %	19.035	19.011	18.987	18.963	18.939	18.915	18.891
Wt. %	18.582	18.558	18.534	18.510	18.486	18.462	18.438
Wt. %	18.129	18.105	18.081	18.057	18.033	18.009	17.985
Wt. %	17.676	17.652	17.628	17.604	17.580	17.556	17.532
Wt. %	17.223	17.199	17.175	17.151	17.127	17.103	17.079
Wt. %	16.770	16.746	16.722	16.698	16.674	16.650	16.626
Wt. %	16.317	16.293	16.269	16.245	16.221	16.197	16.173
Wt. %	15.864	15.840	15.816	15.792	15.768	15.744	15.720
Wt. %	15.411	15.387	15.363	15.339	15.315	15.291	15.267
Wt. %	14.958	14.934	14.910	14.886	14.862	14.838	14.814
Wt. %	14.505	14.481	14.457	14.433	14.409	14.385	14.361
Wt. %	14.052	14.028	14.004	13.980	13.956	13.932	13.908
Wt. %	13.599	13.575	13.551	13.527	13.503	13.479	13.455
Wt. %	13.146	13.122	13.098	13.074	13.050	13.026	13.002
Wt. %	12.693	12.669	12.645	12.621	12.597	12.573	12.549
Wt. %	12.240	12.216	12.192	12.168	12.144	12.120	12.096
Wt. %	11.787	11.763	11.739	11.715	11.691	11.667	11.643
Wt. %	11.334	11.310	11.286	11.262	11.238	11.214	11.190
Wt. %	10.881	10.857	10.833	10.809	10.785	10.761	10.737
Wt. %	10.428	10.404	10.380	10.356	10.332	10.308	10.284
Wt. %	9.975	9.951	9.927	9.903	9.879	9.855	9.831
Wt. %	9.522	9.498	9.474	9.450	9.426	9.402	9.378
Wt. %	9.069	9.045	9.021	9.000	8.976	8.952	8.928
Wt. %	8.616	8.592	8.568	8.544	8.520	8.496	8.472
Wt. %	8.163	8.139	8.115	8.091	8.067	8.043	8.019
Wt. %	7.710	7.686	7.662	7.638	7.614	7.590	7.566
Wt. %	7.257	7.233	7.209	7.185	7.161	7.137	7.113
Wt. %	6.804	6.780	6.756	6.732	6.708	6.684	6.660
Wt. %	6.351	6.327	6.303	6.279	6.255	6.231	6.207
Wt. %	5.898	5.874	5.850	5.826	5.802	5.778	5.754
Wt. %	5.445	5.421	5.397	5.373	5.349	5.325	5.301
Wt. %	4.992	4.968	4.944	4.920	4.896	4.872	4.848
Wt. %	4.539	4.515	4.491	4.467	4.443	4.419	4.395
Wt. %	4.086	4.062	4.038	4.014	3.990	3.966	3.942
Wt. %	3.633	3.609	3.585	3.561	3.537	3.513	3.489
Wt. %	3.180	3.156	3.132	3.108	3.084	3.060	3.036
Wt. %	2.727	2.703	2.679	2.655	2.631	2.607	2.583
Wt. %	2.274	2.250	2.226	2.202	2.178	2.154	2.130
Wt. %	1.821	1.797	1.773	1.749	1.725	1.701	1.677
Wt. %	1.368	1.344	1.320	1.296	1.272	1.248	1.224
Wt. %	0.915	0.891	0.867	0.843	0.819	0.795	0.771
Wt. %	0.462	0.438	0.414	0.390	0.366	0.342	0.318
Wt. %	0.009	0.005	0.001	0.000	0.000	0.000	0.000

PROPERTIES AND COMBUSTION GAS COMPOSITION

0.2

IDEAL GAS

	2600.00	2700.00	2800.00	2900.00	3000.00	3100.00	3200.00
1	22.0000	22.0000	22.0000	22.0000	22.0000	22.0000	22.0000
2	22.0000	22.0000	22.0000	22.0000	22.0000	22.0000	22.0000
3	22.0000	22.0000	22.0000	22.0000	22.0000	22.0000	22.0000
4	22.0000	22.0000	22.0000	22.0000	22.0000	22.0000	22.0000
5	22.0000	22.0000	22.0000	22.0000	22.0000	22.0000	22.0000
6	22.0000	22.0000	22.0000	22.0000	22.0000	22.0000	22.0000
7	22.0000	22.0000	22.0000	22.0000	22.0000	22.0000	22.0000
8	22.0000	22.0000	22.0000	22.0000	22.0000	22.0000	22.0000
9	22.0000	22.0000	22.0000	22.0000	22.0000	22.0000	22.0000
10	22.0000	22.0000	22.0000	22.0000	22.0000	22.0000	22.0000

1	22.0000	22.0000	22.0000	22.0000	22.0000	22.0000	22.0000
2	22.0000	22.0000	22.0000	22.0000	22.0000	22.0000	22.0000
3	22.0000	22.0000	22.0000	22.0000	22.0000	22.0000	22.0000
4	22.0000	22.0000	22.0000	22.0000	22.0000	22.0000	22.0000
5	22.0000	22.0000	22.0000	22.0000	22.0000	22.0000	22.0000
6	22.0000	22.0000	22.0000	22.0000	22.0000	22.0000	22.0000
7	22.0000	22.0000	22.0000	22.0000	22.0000	22.0000	22.0000
8	22.0000	22.0000	22.0000	22.0000	22.0000	22.0000	22.0000
9	22.0000	22.0000	22.0000	22.0000	22.0000	22.0000	22.0000
10	22.0000	22.0000	22.0000	22.0000	22.0000	22.0000	22.0000

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